Feeding Poultry

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Feeding Poultry

GUSTAVE F. HEUSER

PROFESSOR OF POULTRY HUSBANDRY, NEW YORK STATE COLLEGE OF AGRICULTURE AND THE SCHOOL OF NUTRITION, AND POULTRY HUSBANDRYMAN, AGRICULTURAL EXPERIMENT STATION, CORNELL UNIVERSITY, ITHACA, NEW YORK

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PREFACE

As stated in the first edition, this book is a product of the direct responsibilities that I have had in connection with instruction and research in poultry nutrition. During this period of nearly forty years most of my time and my efforts have been applied specifically to the field of poultry feeding. I have also been privileged to visit most of the experiment stations in the United States and Canada as well as a number in Europe.

The material here presented covers my experience in Cornell University as well as reports from the Agricultural Experiment Stations and other public institutions. Such technical journals as Poultry Science, Journal of Nutrition, Journal of Biological Chemistry, and Archiv für Geflügelkunde, as well as such trade journals as Feedstuffs, Flour and Feed, and The U. S. Egg and Poultry Magazine have been drawn upon for source material.

Many changes in the feeding and management of livestock have taken place over the period of years, and many of these changes have been very extensive. In the present century feeding has become a science. Much of this knowledge, for lack of time or information, is not available to the practical poultryman or even to many persons in institutional work. It is the object of this book to make this information more generally available.

The field of poultry nutrition is a rapidly changing one. The present edition includes the information dealing with the recent advances, such as the use of antibiotics. Much of the material has been rewritten. For convenience and also ease of comparison the recommended rations have been grouped in an appendix.

Both the scientific and practical facts relating to poultry feeding are presented in this book. Information dealing with poultry nutrition is quite extensive. However, much of it is scattered and much is contradictory. Because of the latter fact, it frequently must be evaluated, and this I have attempted to do. Usually a summary has been made of the available data, using as much detail as is necessary for illustrative material. In most cases, the references have been cited so that the reader, if he wishes to do so, can obtain more details than are given in the book.

This book is designed to meet the needs of poultry students,

practical poultrymen, feed dealers, and all other persons interested in poultry feeding.

I wish to acknowledge the assistance of all those persons who have been associated with me in teaching and experimental work. I also wish to acknowledge my indebtedness to many friends for various kinds of assistance, support, and inspiration.

G. F. HEUSER

Cornell University
Ithaca, New York

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gives the following information on feeding as applying to the general farm condition:

There is no kind of food, animal or vegetable, that is not acceptable to the hen. She will pick up the hardest, flinty substances, seize all kinds of insects, regale herself on seeds of every description, and finds a variety in the leaves of the grasses and weeds. All kinds of refuse and waste material from every source, as well as the droppings of cattle, afford her luxuries that would possess but little attraction for larger stock.

Special foods in the summer season are unnecessary, as the hen is capable of selecting and securing a sufficiency of all that is required for supplying her needs; but there are periods when it becomes necessary to assist her, as the production of substances that are to be deposited separately from the body demands certain elements that may be beyond the power of the hen to procure during those seasons when she is really a prisoner and deprived of her liberty.

The hens that thrive on a diet of corn during the summer do not derive their nutriment from the corn alone, but from the variety of forage secured, and as the hen is more prolific during the warmer season she keeps in better condition for laying by the rapid conversion of the food into eggs instead of into fat; but overfeeding will eventually result in fatty degeneracy of the liver.

Among the foods sometimes allowed that may be considered out of the regular course are sunflower seeds, linseed meal (or oil cake), rape seed and millet seed, which, though highly nitrogenous, contain large proportions of oil, and are therefore fattening also; while the oils from them induce the shedding of the feathers, causing premature molting.

The most important of all foods is finely chopped clover hay scalded and fed in troughs. It is rich in mineral matter, nitrogenous, contains a large proportion of carbonaceous matter, and by its bulk reduces or dilutes the concentrated grain food. It is very necessary that a plentiful supply of sharp, gritty material be always kept within reach of the hens, as they can not derive full benefit from any kind of food unless complete mastication results.

However, concentrated poultry production with more attention to feeding was already developing. In the same book Mr. Collingwood gives the accompanying tabulation to show the ration that had given the best results for egg production for 600 hens, this being the method used by C. H. Wyckoff at Groton, New York.

1. Morning, by weight all they can eat of the following mixture. One-half bran, one-fourth corn and one-fourth oat-meals mixed with hot water or milk, with ½ pint of salt, 1 quart of charcoal and 1 bushel of clover hay cut fine. If there be no milk add 16 pounds of chopped meat and 1 bushel of beets cut fine.

2. Noon, whole grain by measure. One part oats, 1 buckwheat, and 1 wheat, give 1 quart to 50 hens in chaff

3. Night, the same as No. 2, all they will eat

4. Drink, milk or pure water.

At the turn of the century the hens did not lay large numbers of eggs, and most production usually took place during the spring of the year. The important condition, however, was the fact that the number of hens was not much greater than the natural food supply on the farm. They fed upon such protective feeding stuffs as greens and milk and also consumed considerable whole animal life, for example, bugs and worms. They lived outdoors to a large extent and benefited by direct sunshine.

From this condition the poultry industry in all its phases has developed until at the present time we have fairly definite and often quite complex systems and methods. The number of hens has greatly increased, and they have been so concentrated that they have far exceeded the natural food supply. The birds have been bred for increased production to the extent of obtaining high flock averages as well as individual records. Combined with this we have a greater proportion of the production out of the natural season. Not only table eggs but also hatching eggs are being produced the year round. Early fall production from pullets requires earlier hatching in the spring. Furthermore, many flocks are being kept in more or less close confinement, or even in complete confinement, throughout the entire laying year.

The same situation applies to the young. Larger numbers of chicks are being produced, many of them out of the natural season or at those times of the year when conditions are not favorable. There has been greater development along the lines of mass production of chicks under factory methods. Hundreds of thousands of birds, especially broilers, are raised in batteries under conditions of strict confinement.

Whenever animals are made to produce out of their natural season, it is necessary to introduce artificial methods to a greater or lesser degree. This introduces factors which complicate the problem. A comparison of conditions today, as contrasted with those of a few generations ago, helps to give one an appreciation of some of the factors that are helping to make poultry feeding a more complicated problem.

It must also be borne in mind that the natural foods and those consumed more or less in their entirety were complex when viewed from their feeding value. In substituting for those feeds we run the risk of omitting some of the factors supplied in them. Furthermore, modern methods of manufacture are changing the nature of some feeds. A ration that contains *degerminated* cereals or cereal by-products might be deficient in vitamins

whereas the same mixture with regular products would supply plenty. Meat scraps is a variable product depending upon the nature of the raw material and the process of manufacture. In recent years most of the organs of the animal, such as the liver, are diverted to other channels so that at the present time larger proportions of connective tissue and bone and other less valuable portions are forming the raw material for meat scraps. The method of preparing any feed and the conditions of temperature and oxidation to which it is subjected will affect the feeding value. In the more intensive manufacturing processes, there is a greater likelihood of destruction of some factor. But the important point is that these changes, which are altering the feeding value of products, often cannot be detected by analysis or inspection. Neither does the average feeder know or realize that the nature of many feeds is changing.

There is also the possibility that some of our feeds are undergoing change in composition owing to changes in the supply of the elements in the soil. Depletion of minerals or conversion of them into an insoluble form might render them less available to the plant. It is suspected furthermore that conditions of drought might influence the nutritive value of the feed produced.

EVOLUTION OF MODERN METHODS

At the present time there are in use certain systems of feeding practice. They are the result of development or evolution, based more or less on experience. This development has proceeded along certain lines, which have been influenced by certain facts and conditions. Practically all the knowledge that we have of scientific feeding has been secured within comparatively recent years. As late as the latter part of the last century, poultry was fed by rule almost entirely. The method was one which some one had stumbled upon by accident, but it seemed to get results.

Previously only feeds grown on the farm were used. The ration was thus restricted to the grains produced and to any waste products or by-products of the farm or of the home. Now we have developed a considerable number of specially prepared poultry feeds, which have no restrictions of ingredients, since modern development in transportation has linked all parts of the world and made practically any product available.

There has also been a development in methods of feeding and feeding practices. At first, the hens more or less fed them-

selves, very little attention being given to any definite or regular system of feeding. Gradually more attention was given to the birds. At first they were hand fed practically entirely on grain. Then systems of hopper feeding developed in which the hens could help themselves.

The hopper itself has undergone considerable changes. In some cases the hoppers were made large enough to hold supplies of mash for a month or more. It is doubtful whether that is the best practice since it encourages neglect of close observation of the birds and also increases the chance of spoilage of the feed. The present-day tendencies are to practice a closer check-up on feeding. This practice has eliminated the very large hoppers and substituted smaller ones of the open type.

The introduction of ground feeds, fed as mashes, was a distinct advance in poultry feeding. Man found out that he could assist the hen by furnishing part of the grain already ground. So we have systems of feeding ranging from all grain to all mash, with nearly all the possible combinations of proportions of grain and mash between these extremes.

Another variation was the condition in which the mash should be fed, that is, wet or dry. The wet mash was probably fed first. Later the dry mash system of feeding was introduced and used exclusively in many cases. At present the generally recommended system is more likely to be a combination of the two. The dry mash is kept available all the time and may be supplemented with a wet mash when it is necessary to increase mash and food consumption.

When hoppers were introduced in poultry feeding they were used for grain as well as for mash. The hopper system of feeding grain was soon abandoned because it was believed that the hens did not get sufficient exercise. Grain, therefore, was fed in a litter of some kind, the depth of which has also gone through various evolutions. Recently the swing has been back again to hopper feeding of grain, chiefly because of the sanitary advantages that it offers. The ground feed is almost universally fed in hoppers. Hopper feeding of dry mash gives all the hens a more nearly equal chance, allowing them an opportunity to eat at any time and preventing crowding, incidental to feeding a wet mash to larger flocks.

Can a hen balance her own ration? Many theories and opinions have been advanced. As a matter of fact, she comes very near to doing it when she is given a choice of grain and mash. The mash, if properly composed, is rich in protein, vitamins, and

minerals while the grain contains more of the energy nutrients. Therefore, the hen eats from both the grain and mash as much as she wants of each and balances her own ration fairly satisfactorily. But the question has not yet been settled as to whether the hen should eat each of the different feeds separately. Feeding each ingredient separately has been tried, but in most cases has not proved satisfactory.

Other practices have been evolved, and no doubt the future holds in store still more. At the present time there is a further development of the all-mash system, which endeavors to obtain some of the advantages of grain feeding. There are cubed feeds or pellets and kernels, which consist of binding an all-mash combination into larger particles. Also, systems of cooking, predigesting, and other methods of processing foods have been tried to a greater or lesser extent and will need to be given further consideration in the future.

CAUSES OF EVOLUTION OR CHANGES IN FEEDING

No doubt there are many reasons for the changes and developments just discussed. Increased population and concentration of population in cities, where eggs and poultry cannot be produced in sufficient amounts, have resulted in an increased demand for the products. This increased demand for poultry products has resulted in an increased number of hens. The increase in the number of hens has made it necessary to introduce other systems of feeding because the number of hens on the farm has got beyond the natural food supply.

The development of the industries supplying human food has had an influence on animal feeding. It is only within the past few generations, for example, that the production of prepared cereals has developed extensively. This preparation of cereals has given rise to a considerable supply of by-products which have merit and are valuable from the feeding standpoint

The milling industry has long been furnishing wheat by-products which are utilized in animal feeding. But, owing to changes in manufacture, changes have also occurred in the nature of these feeds. The present-day products are milled more closely than previously. Particularly is there a change in the amount of germ that is contained.

We also have the by-products of the packing industries, which enter largely into our poultry feeding, especially as a source of protein feeds. The same may be said of the fish and milk indus-

tries. In fact, any industry which produces a by-product has had a connection with, or has a potential relation to, animal feeding. The feeds and the system of feeding animals, and therefore also poultry, have been modified to make use of these valuable by-products.

Then, of course, our increased knowledge of nutrition, especially of the results of research carried on by the experiment stations, has given us some basis for making changes in our feeding system. A fund of knowledge of the composition of feeds is accumulating. By chemical analysis, as well as by biological analysis, we have gradually been able to group the various feeds according to their nutrients. This knowledge in connection with some information of the nature and composition of poultry of various kinds and of eggs has enabled us to modify rations to meet the conditions more intelligently.

The knowledge of the processes taking place in the body is important. Facts concerning the digestion of feeds have been difficult to obtain because in the fowl the feces and urine are eliminated together, so that it is difficult to separate waste or broken-down parts of the body from undigested food. Still, the discovery that poultry does not handle fiber or roughage has greatly influenced the make-up of our rations. We now know that laying hens require a very considerable amount of calcium to make eggshells, and the calcium can best be furnished in the carbonate form. We are in possession of certain facts showing the effects of different feeds upon production and the quality of the product. For instance, we realize the value of using animal protein feeds, appreciate the importance of green feed, and have found out the possibility of affecting the color and appearance and nutritive value of the egg by feeds.

We have many facts on the requirements of the laying hen. We know that the early growth of chicks is rapid and that the ration must supply a large amount of protein to meet this rapid growth. The information concerning vitamins has been accumulating so rapidly, that we hardly know how far reaching their influence is.

Yet every time that we get further information, definite facts regarding any phase of the feeding question, it enables us to meet the conditions more intelligently.

NEED FOR MORE EXACT KNOWLEDGE

We have at the present time a reasonably satisfactory knowledge of poultry feeding which enables us to proceed in a fairly

intelligent manner. Comparatively, however, this knowledge is still incomplete. That is true particularly if we consider it from the standpoint of the basic knowledge and facts concerning fundamental principles underlying nutrition. Our feeding, even at the present time, is to a considerable extent based upon experience or the trial-and-error method. It is guided by accumulations of ideas and practices handed down from the past. However, a rule-of-thumb method will apply mainly insofar as the same conditions are met in all respects. For example, if we have the same type of bird, of the same weight, producing the same numbers of eggs, feeding her the same feed of exactly the same composition, quality, and make-up, under the same conditions of management or environment, we can expect to get the same results. But when we have a variation in any one or more of the almost numberless factors which affect responses, we are likely to get different results unless we have fundamental information and can meet the new conditions on the basis of this information.

Since our present feeding practices are the result of generations of experiences, they contain much that is unnecessary. They still include things that happened to be incidental rather than essential. Therefore, it is no wonder that we are constantly questioning to determine the essentials. Many things have been found unessential or at least very much decreased in importance. Hence the present tendency is also toward simplification.

However, before it is safe to modify the old, it is necessary to have reliable information, especially if the modification is radically different from the commonly accepted practice. We need to secure fundamental information which can be obtained only in solving a problem by refined experimental methods. This means that all conditions should be under control and only one factor varied at a time. Even then, what is now considered fundamental may later be shown to be otherwise and there may be wrong interpretations of results. For example, in the early study of vitamins, opthalmia, a symptom of vitamin A deficiency, was referred to by one of the first investigators as malnutrition in infants due to a lack of fat in the diet, because the eye trouble could be relieved by cod liver oil, whole milk, or cream mixtures. We now know this to be untrue, but it was thus interpreted because the fats, which this investigator chose, chanced to be good carriers of vitamin A. Similarly, where protein is involved in the growth of chickens, some of the beneficial results have been attributed to added protein, whereas they might have been

due to increased amounts of vitamins which were also present.

However, even though there are misinterpretations at times, we benefit by this information. By means of these steps we arrive at a factual or scientific basis. In the end, the accumulation of knowledge makes possible clarification and proper interpretation of facts. It is such information that we need in order to have a clear understanding of the various feeding problems.

APPROACH TO AN UNDERSTANDING OF THE FEEDING PROBLEM

To gain a proper understanding of the feeding problem, we need to get information on the various phases having an influence upon it. In the first place, we need to have a knowledge of the chemistry of both plants and animals. We need to know the make-up of the plants because they are really the building materials for our animal, which is the finished product or which we might consider as the structure. There are certain relationships between the structure of the plant and of the animal which will help us in understanding our feeding problem. It is a common saying that we feed a part to make a part. That is true to a very large extent and, insofar as it is true, if we know the nature of our feeds and our animals, it will help us considerably in our understanding.

We need to have an acquaintance with the processes that take place in the animal's body. We need to be familiar with the physiology of the animal. That is particularly true of digestion and metabolism, which involve the processes by which feeds become available to the body.

We need also to have considerable knowledge of the feeds themselves, not only of their composition or chemistry but also of their digestibility and such physical characteristics as texture and mechanical condition. We need to get a measure of the value of each feed as compared with others.

We need to know the requirements of poultry for food, which involves the study of feeding standards. Each kind of poultry, as chickens, ducks, geese, and turkeys, has special needs. Limiting the feeding to fowls, our problem is influenced by the purpose for which the birds are kept and by the conditions under which they are managed. The requirements differ for hens producing eggs and for growing chickens or fattening birds. We must know the reactions or symptoms when these requirements are not

met, or when there is even one deficiency or a partial deficiency.

After obtaining such information on the principles of nutrition, we need to transform the science of feeding into the art of feeding. We need to make practical application of the technical knowledge. Unless we have some understanding of why changes are made and what the results are likely to be, it is practically impossible to make any intelligent changes, either in the make-up of the feeds themselves or in the methods of feeding. We need to be able to distinguish between causes and results. For instance, we have found that, when we have included some form of animal protein in the ration, we have obtained better results than when the ration was limited to vegetable proteins. We have also had benefits from including green food in the ration. We need to consider these feeds not only in terms of complex products, such as animal protein feeds and green feeds, but also to view them in terms of their components, as amino acids, vitamins, and minerals. If we can state that our more favorable results are due not to green food but to some specific part or parts, it will help in making changes in the application of feeding.

Such information is particularly important when there are feed shortages, as are experienced during a war. It is then necessary to make substitutions for commonly used ingredients. The results of such substitutions will be effective to the extent that the ingredients used replace the necessary nutrients of the feed omitted.

Present-day research in nutrition may be considered primarily a means or a method by which we expect to secure such information. The general line of approach is: (1) to find out what the specific requirements are, quantitatively, in respect to the various factors, such as amino acids, vitamins, and minerals, (2) to determine how much of each of these factors the various poultry feeds contain and the physiological effect of these feeds.

When this information becomes available, the formulation of a ration can become a matter of calculation or of simple arithmetic. Obviously, however, the time is still distant when the formulation of rations and of feeding practice becomes such a simple and mechanical procedure

FIFTY YEARS OF ACHIEVEMENT IN POULTRY NUTRITION

It can be truthfully said that more progress has been made in feeding poultry during the past 50 years than was made during the preceding 500 or even 1000 years.

The first decade of the present century might be called the era of barnyard feeding. Feeding was simple, and there was little knowledge of the nutritive requirements of poultry.

During the period of 1910-1920 commercial feeds became available, mash mixtures were fed, the importance of animal proteins was stressed, and feeds were purchased according to gross chemical analysis. The poultry flocks were larger, special houses and care were provided, and the rations were becoming more complex.

The third decade can be called the beginning of the vitamin era. The importance of the sunshine vitamin—vitamin D—was discovered. Cod liver oil substituting for sunshine made complete confinement and year-round production possible. This really was the basis for the extensive commercial poultry production which we now have.

During the period of 1930-1935 the importance of other vitamins was emphasized. Riboflavin, the important vitamin in milk, was shown necessary for improved hatchability and proper chick development. The introduction into the ration of such ingredients as "fermentation products" allowed for greater flexibility in feed formulation.

The latter part of this decade focused attention on the mineral balance of the ration. The discovery of the importance of manganese in preventing perosis made possible the expansion of the commercial broiler industry.

During the first half of the 1940 decade attention was centered upon protein and the amino acids. Amino acid requirements were being determined and methods developed for amino acid analyses. An increased use of vegetable proteins emphasized the nutritive value of feeds from animal sources. This stimulated interest in the animal protein factor, the discovery of vitamin B_{12}, and the use of antibiotics in poultry feeds.

Present day feeding is very largely based upon nutrition science. The practical nutritive requirements are largely known. A large variety of ingredients from all over the world are used in the commercial feeds which furnish the raw materials for the present large scale production. Instead of wanting to know only the protein, mineral, and vitamin values of the feeds, the nutri-

tion science of today is interested in nearly fifty of the components of these general nutritive groups.

What of the future? There is still much to be learned before a state of perfect nutrition is reached. There are still unknown vitamins and possibly other unknown nutritive factors. Much needs to be found out concerning physiological factors, including the effects of hormone feeding. Also the investigator has been aware for some time of the existence of interrelationships between certain nutrients. These are becoming better understood and will be of more importance in formulating rations since many of these relationships involve sparing actions upon other nutritive factors. More progress can also be made in developing rations and birds that will produce more efficient and hence more economical poultry and eggs.

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CHAPTER 2

OBJECTS AND PRINCIPLES IN FEEDING POULTRY

What purposes or objects do we have in mind when feeding poultry? The answer will depend upon the point of view. The problem can be approached in different ways.

TRANSFORMATION OF FOOD

In general, we might say that the object of feeding animals is to manufacture some product that is useful to man. In the case of poultry, the products are chiefly eggs and meat. Animal feeding deals with the transformation of food into animal products. With poultry, this involves grains, by-products of various industries, greens and vegetables, and minerals.

Some of the feeds used for poultry could be included directly in the human diet. When fed to livestock, the feed that could be eaten by man is transformed into a more desirable form. For instance, wheat, corn, and oats are utilized as chicken meat or eggs rather than cereals. Or we might say that most of us would prefer to eat our corn and wheat, or at least the greater share of it, as eggs and chicken meat.

Animal feeding might involve the transformation of so-called nonedible products into edible form. Very often waste and by-products, not usually considered a part of the human diet, are fed. We might mention wheat bran, meat scraps, fish meal, and gluten meal as examples of this kind.

In some cases the hen conserves food energy which might otherwise be lost. This is true where table scraps are fed, and when the hen can range on the farm, picking up waste grains here and there and making use of green food and insect life.

In this connection, it might be well to ask whether the hen is an efficient transformer of feed into a finished product Dr. W. H. Jordan,[1] of the New York Experiment Station at Geneva, has compared a Leghorn fowl that weighs 3½ pounds and lays 200 eggs, weighing 25 pounds, with a Jersey cow that weighs 1000 pounds and gives, in a year, 7000 pounds of milk containing

14 per cent solids. He says: "If you take the dry matter of the hen and compare it with the dry matter in the eggs she lays in a year, there will be 5½ times as much dry matter in the eggs as in her whole body. The weight of the dry matter in the cow's body to the weight of the dry matter in the milk well be as 1 to 2.9. In other words, based upon the dry matter, the hen does twice as well as the cow. I suspect the hen is the most efficient transformer of raw material into a finished product that there is on the farm. Her physiological activity is something remarkable. So in that particular the hen stands in a class by herself." It is not exceptional for a 4-pound hen to lay 250 eggs in a year. This would represent 31 pounds of eggs, containing 4.1 pounds of protein, 3.3 pounds of fat, and 3.1 pounds of calcium carbonate.

Viewed from a different standpoint, the hen is not so efficient as the dairy cow. For example, Jordan also compares the quantities of the various animal products and of human food in animal forms which can be produced by the use of a quantity of cattle food containing 100 pounds of digestible organic matter, as follows:

Animal	Marketable Product, lb.	Edible Solids, lb.
Cow (milk)	139 0	18 0
Swine (dressed)	25.0	15.6
Cow (cheese)	14.8	9.4
Calves (dressed)	36.5	8.1
Cow (butter)	6.4	5.4
Poultry (eggs)	19.6	5 1
Poultry (dressed)	15.6	4.2
Lambs (dressed)	9.6	3.2
Steers (dressed)	8.3	2.8
Sheep (dressed)	7.0	2 6

There is also some difference in efficiency when the various food nutrients are considered. Jennings[2] gives the following values of human food produced by 10 units of feed:

Animal	Calories	Protein	Calories plus Protein, Index
Cow (milk)	4627	0 52	2 54
Layers (eggs)	1260	0 23	0.99
Hogs (meat)	3629	0 14	1 16
Turkeys (meat)	1522	0 26	1 14
Sheep and lambs (meat)	1880	0 21	1 04
Chickens (meat)	958	0 22	0 92
Beef (meat)	837	0 12	0 56

The comparisons above take into consideration only quantities. Furthermore, the energy content of the egg is not the sole reason for its use. Perhaps what is more important is the quality of these various products and the place they fill in the human diet. When considered on this basis, eggs compare very favorably with milk.

Halnan[3] gives the efficiency of conversion of feeding-stuff protein to human-food protein by determining the pounds of protein produced from 100 pounds of digestible protein, when fed to the different farm animals.

	Pounds
Cow (as milk—600 gallons a year)	35.8
Hen (as eggs—140 a year)	31.6
Pig (as pork)	21.2
Hen (as meat)	18.0
Bullock (as baby beef)	7.8
(as Norfolk beef)	5.9
(as grass beef)	5.4

Halnan also reported the 100-pound protein equivalent yields, as given by Leitch and Godden, as follows:

	Pounds
Cow (as milk—2 gallons a day)	35.1
Hen (as eggs—200 a year)	26.4-29.8
Pig (as pork)	19.0
Hen (as meat)	21.8-26.3
Baby beef	15.5
Sheep (as lamb)	13.2
Fat bullock	8.7-8.9

Almquist,[4] *reporting on the efficiency of conversion of feed to* food, indicates the following conversion efficiencies for protein and fat in the various edible animal food products. The following percentages of the feed protein consumed are recovered in the edible food protein:

	Percentage
Milk	32.5
Eggs	22.9
Meat birds	16.4
Swine	11.0

The fat in the edible parts, expressed as percentage of the potential feed fat, varied as follows:

	Percentage
Swine	23.5
Milk (25 pounds daily)	21.4
Layers (200 eggs a year)	13.5
Turkeys (all types)	8.4
Meat birds (all types)	3.9

On the other hand, Brody, Funk, and Kempster[5] state: "It appears that the net energetic efficiency of egg production (not counting maintenance) is perhaps of the same order as of milk production, but that the gross energetic efficiency of egg production (including maintenance of fowl) in 'good' layers is only about half the efficiency of milk production in 'good' dairy cattle."

The difference in the gross energetic efficiency of egg and milk production is attributed to the greater structural complexity of egg than of milk, more biologic time taken to produce the unit of egg energy, and the greater energy expense for producing the egg calorie which contains relatively more fat produced from a carbohydrate diet.

Bird and Sinclair[6] state that the efficiency of feed utilization for pure egg production ranges from about 75 per cent in the somatically immature birds to about 60 per cent (of the same order as for milk production in cows) subsequent to somatic maturity.

Differences exist between individuals in the efficiency of feed utilization.[7] Male chickens were reported as being slightly more efficient than females. Fast-growing individuals utilize their feed more efficiently than slow-growing individuals. There appear to be differences between breeds and strains in this respect The evidence also indicates the heritability of efficiency of feed utilization.

MEETING PHYSIOLOGICAL NEEDS

We might also consider our purpose in feeding from the physiological standpoint. We feed first to maintain the animal. Maintenance is usually considered the first law of nature. By maintenance we mean keeping the animal in equilibrium, with neither gain nor loss in weight. Heat must be provided to keep up the body temperature. The body temperature of poultry is considerably higher than of other farm animals. According to Fronda,[8] the fowl and guinea hen have a temperature of approximately 107° F., the duck and pigeon 108° F., the turkey 106° F , and the goose 105° F. Energy must be supplied for all action, both voluntary and involuntary. Voluntary action includes such activity as scratching, walking, and flying; involuntary action is connected primarily with body processes, such as digestion and the like.

Material must be supplied to renew the body tissues which are being constantly worn out and to provide for the various body secretions. The more important of these secretions are the various juices concerned in digestion

The maintenance requirement of poultry is very considerable. This requirement takes the major proportion of the feed consumed. If the mature hen is out of production nearly all the feed is used for this purpose. Even if the hen is in heavy production, probably at least 70 to 80 per cent of her food is needed for maintenance. Joshi, Shaffner, and Jull[9] reported that, with hens laying at the rate of 72 per cent, approximately 71 per cent of the food consumed was used for body maintenance, 27 per cent for the production of eggs, and 2 per cent for increase in body weight. Brody, Funk, and Kempster[5] report the gross energetic efficiency (the percentage of the feed energy which appears in the egg) for Leghorns as follows:

	Percentage
100-egg producers	11
150-egg producers	14
200-egg producers	17
250-egg producers	20
360-egg producers	27

For young stock, the proportion of feed needed for maintenance is smallest early in life when the chick is growing rapidly and increases as the chick grows older and the rate of growth is slowed down. Records of experiments with White Leghorn chicks at Cornell University indicate approximately 65 per cent of the food used for maintenance the first month, 75 per cent the second, 80 per cent the third, 85 per cent the fourth, and 90 per cent the fifth month.

After the animal is maintained, an increase in tissue can occur. In young stock this is called growth; in mature birds it might be fattening. *Growth in the young animal is chiefly an increase in* water, protein, and minerals; in the mature animal it might be fat.

Excess food may also be used for the production of a useful product and for reproduction (the development of a new individual). These two are mentioned together because, in the case of the fowl, production and reproduction are the same process. That is not true of other farm animals. Milk production in the dairy cow is a separate process from reproduction.

Production or reproduction in poultry must not take place before growth is well advanced; otherwise there is danger of stunting. Reproduction necessitates complete production; and, so far as the hen is concerned, she will endeavor to produce a complete egg, which is capable of reproducing herself. The animal in a

reproductive state is more intensely nervous. Since abundant production is desired, there is obviously an intense strain on the vitality of the bird. Unless there is an abundant and proper feed supply to keep up body reserves and maintain health and vitality, we shall fail to get not only hatching quality but production as well.

SOME PRINCIPLES OF FEEDING POULTRY

Food furnishes the fuel which is burned in the body. An essential part of this burning process is oxygen. The amount of oxygen needed depends upon the chemical composition of the material that burns in the animal. The rate of metabolism regulates the amount of oxygen absorbed and the carbon dioxide given off.

The phenomena of life are composed of phenomena of motion due to the liberation of energy locked up in the feed. These motions are manifested chiefly as heat, mechanical energy, and electric currents.

The feeding of poultry involves certain special considerations not encountered in feeding other farm animals. First, there are the physiological considerations. All the body processes are conducted in shorter time. Digestion is more rapid. Respiration and circulation are faster. The body temperature is 8 to 10 degrees higher. A greater amount of body surface is exposed per unit of weight. The individuals show greater activity. They are more sensitive to external influences. They mature early. Production is always full and complete, or there is none. The hen does not lay half an egg The young stock has wonderfully quick growth, the young chick often increasing its weight ten times or more in 5 weeks.

All these facts indicate that in poultry we are dealing with animals that require a high rate of metabolism. It must, therefore, be kept in mind that the requirements are thus more exacting and the balance or equilibrium more easily disturbed.

There are also certain anatomical considerations which must be kept in mind. The hen grinds all her feed in the gizzard. Since the capacity of the digestive tract is limited and since fiber is practically indigestible, there is danger of a lack of sufficient nutriment when the feeds are very coarse. To avoid this danger more concentrated feeds must be fed, which might introduce other difficulties. It is necessary, therefore, to maintain a proper balance between the bulky and the concentrated feeds.

Certain management considerations are also involved when

comparing the feeding of poultry with the feeding of the larger farm animals. A greater number of individuals are represented per man unit, increasing the need for closer scrutiny and observation of condition of the animals. Furthermore, the birds are *fed collectively rather than individually*, as the larger animals are. In the flock birds of many states of nutrition are likely to be represented, and they require different rations or methods of feeding. Management that gets the best results from one part of the flock will not get the best from another part and might actually be detrimental. However, in order to overcome this difficulty to the greatest degree, there is need for flock segregation in which birds nearly alike in physical condition, age, sexual maturity, and production, and therefore in nutritive requirements, are placed in separate units and fed accordingly.

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CHAPTER 3

COMPOSITION OF PLANTS, ANIMALS, AND RATIONS

THE FEED NUTRIENTS AND THEIR FUNCTIONS

All feeds are composed of several distinctly different groups of substances, which are called nutrients. These nutrients have definite functions or uses in the body. A continued deficiency of them will result in general debility, which finally will end in death.

In practical feeding, it is not the separate nutrients which are dealt with, because most natural feeds are mixtures of nutrients. No two feeds are alike in that they contain these nutrients in the same proportions. Each feed is likely to contain a larger proportion of one or more of the nutrients. These differences make it necessary to regulate the amount of the different feeds used so that the total of each nutrient furnished by the ration as a whole will be correct.

Most of our feeding stuffs come from plant material. The plant tissues are derived from the inorganic matter of the soil and air with the aid of energy from the sun. Approximately twenty different chemical elements are generally found in plant and animal tissues. They are combined into the compounds known as nutrients. The recognized nutrients are carbohydrates, fats, minerals, proteins, vitamins, and water.

WATER. Water is a compound composed chemically of 2 parts of hydrogen and 1 of oxygen. The amount which occurs in feeds is quite variable. Green or succulent feeds may contain as much as 80 to 90 per cent of water. In kiln-dried feeds, the amount present may be as low as 5 per cent, whereas the ordinary grains usually contain 10 to 12 per cent of water.

A large proportion of both the body of the fowl and the egg is composed of water. More than half of the body and 2/3 of the egg are water. Since the body of the hen and likewise her product, the egg, contain more water than solid material, water is an important ingredient of any poultry ration. The ordinary poultry ration is composed of feeds containing a relatively small amount of water, which will supply only a part of the requirement for

this nutrient. Hence special attention must be given to the water supply. Water is necessary for all the body activities. It is the medium in which the different body processes take place. It also regulates the body temperature.

Very often the water supply is neglected. It is just as essential as feed. In fact, a hen can live for a longer period without feed than she can without water. It is not possible to supply sufficient water to the hen by giving her access to it once or twice a day, as is done with the larger farm animals. Hens must have a continuous supply of water for they drink only a small amount at one time. Especially with dry-mash feeding, it is necessary to have water available whenever feed is available. During freezing weather and where artificial illumination is used, some provision should be made to keep the water from freezing. The hens will also appreciate having the chill removed from the water and will consume larger amounts of it.

MINERALS.[1] The mineral portion of the feed or animal body is also known as the ash or inorganic matter. Only about a dozen, or perhaps fifteen, are thought to be necessary for the animal body. The inorganic matter appears chiefly as phosphates, sulphates, carbonates, chlorides, nitrates, iodides, or silicates of sodium, potassium, calcium, magnesium, iron, copper, manganese, or zinc.

Minerals are important to the animal, but they must be present in the right concentrations. The animal body can tolerate some variation in this respect, but considerable departure from the normal is likely to be detrimental.

Some minerals, such as manganese, cobalt, copper, iodine, and iron, are required only in very small amounts and are called trace minerals.

Location of Minerals. Minerals enter into the composition of all body tissues. Their distribution, however, is not uniform since one finds concentrations of certain minerals in different tissues. For example, the bones are a storehouse for minerals, especially calcium, phosphorus, and magnesium. The shell of the egg is made up largely of calcium. On the other hand, the yolk of the egg has larger proportions of phosphorus and sulfur. Potassium is found abundantly in such tissues as muscles, glands, and nerves. Sodium is found in large amounts in blood and lymph. Phosphorus and sulphur enter into the composition of proteins. Chlorine is a constituent of the hydrochloric acid of the gastric juice. Iron is concentrated in the hemoglobin of the blood. Iodine is found chiefly in the thyroid gland; silicon in the feathers. Cobalt is an integral part of vitamin B_{12}.

Function of Minerals. The various minerals are intimately bound up with animal life. They furnish building materials, as a part of bones they provide rigidity to the body, and they help to control the various life processes. They aid in digestion, assimilation, distribution of food nutrients in the body, and excretion. Some of them act as catalysts. Others function as buffers in the blood and tissues. Some are connected with enzyme activation, oxidation processes, and cell regulation. Minerals might also be involved in the activity of the intestinal flora.

Calcium, phosphorus, and magnesium are essential for bone formation. Their utilization is dependent upon the presence of sufficient vitamin D. Calcium is also essential for clotting of the blood. Magnesium is connected with nerve and muscle activity. Phosphorus also functions in the metabolism of carbohydrates and fats. All the common forms of calcium appear to be well utilized. However, some forms of phosphorus are not available to poultry.[2] This is true especially for the phosphorus in feedstuffs of vegetable origin which is largely in the form of phytin. Inorganic phosphorus is readily available. In the ration for the growing chick a ratio of calcium to phosphorus of 1.5:1 is desirable.

Sodium chloride (salt) is the chief inorganic constituent of the blood plasma. The addition of salt to poultry rations is a common practice. Salt metabolism is related to water balance. The amounts should be restricted since excess salt will cause wet droppings and hence wet litter. Excessive amounts of salt are toxic to chickens. (See Chap. 5, section on minerals.)

Sulfur is an essential mineral and is accounted for almost entirely by the sulfur which occurs in organic combination in the amino acids, methionine, and cystine. Inorganic sulfur has little value in the poultry ration.

Iron and copper are necessary for hemoglobin formation. They function in connection with oxygen transfer.

Iodine is necessary for the normal functioning of the thyroid gland. Most of the iodine of the body occurs in thyroxin, the hormone secreted by the thyroid gland, which regulates body metabolism.

Potassium[3] as well as sodium helps to regulate the osmotic pressure in cellular tissue and body fluids. Symptoms of potassium deficiency in the chick include retarded growth, weakness, loss of use of legs, and the excretion of large amounts of urates. Death was preceded or accompanied by tetanic seizures in which the muscles were unable to relax. Bone calcification was influ-

enced by the amount of potassium in the diet. Electrocardiograms of chickens produced on a potassium deficient ration were abnormal.

Mineral Relationships. Certain mineral metabolism relationships exist, for there must be a proper balance of minerals in the body. To some extent the animal can excrete excesses. The bones act as a storehouse for some of the minerals. Calcium is more effectively assimilated in the presence of vitamin D; magnesium salts cause a loss of calcium. Potassium increases sodium elimination, and calcium increases phosphorus elimination. An excess of phosphorus also increases the need for manganese. On the other hand, copper has a favorable reaction in sparing iron. The best results are secured when an optimum ratio of certain of the minerals is maintained, such as a balance between calcium and phosphorus, and between calcium and sodium and potassium.

Acid-Base Balance. Some of the minerals such as sulfur, phosphorus, and chlorine are acid in reaction, whereas others such as calcium, magnesium, sodium, and potassium are basic. It is thought best to use feeds containing these minerals in such proportions as to provide a proper acid-base balance.

Lack of Minerals. Mineral starvation of chickens, due either to an actual lack of minerals in the ration or to their unavailability, results in weak limbs and improper bone development. A general irritability or excitability and even spasms or convulsions may result from a lack of minerals. Where the minerals have specific functions, a lack of them will produce specific deficiencies, such as anemia when iron is deficient, goiter when iodine is lacking, and perosis when there is not enough manganese present. A deficiency of magnesium[4] might cause convulsions accompanied by gasping. Calcium and phosphorus are required in largest amounts in the ration because of the needs for bone and eggshell formation. These minerals function in connection with vitamin D. When not present in sufficient amounts, weak eggshells will be produced and rickets will develop. (See vitamin D, p. 41.)

Other minerals, needed only in small amounts but important to the animal, are the minor elements, manganese[5] and iodine. With shortages of these minerals, specific nutritional deficiency conditions develop.

Perosis and Manganese Deficiency. Perosis[6] is a nutritional deficiency condition due to a lack of manganese and possibly some other factors, such as choline, biotin, or folic acid. It is

sometimes called slipped tendon or enlarged hock disease, owing to the slipping of the tendon and the enlargement of the hock which causes crippling of the bird (Fig. 1). Perosis usually appears when the chicken is 3 to 5 weeks old.

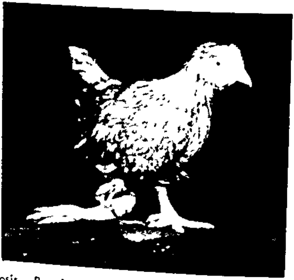

Fig. 1. Perosis. Perosis or slipped tendon resulting from a manganese deficiency. Note the flattened hock and the deformed leg. (Courtesy Cornell University.)

Perosis is a malformation of the bones of chicks. The symptoms usually observed are swelling and flattening of the hock joint, with subsequent slipping of the Achilles' tendon from its condyles. The tibia and tarsometatarsus may exhibit bending near the hock joint and lateral rotation. One or both legs may be affected, but as a rule lameness develops in one leg only. A shortening and a thickening of the long bones of the wings and legs are also observed. The disorder, so far as manganese is concerned, is aggravated by excessive quantities of calcium and phosphorus in the ration.

In laying and breeding birds[7] a manganese deficiency results in lowered egg production, lowered eggshell strength, and lowered hatchability. Numerous embryos that die as a result of manganese deficiency exhibit chondrodystrophy, a condition characterized by a parrot-like beak, wiry down, and shortening of the long bones. This condition is not, however, specific for a manganese deficiency.

An ataxia[8] characterized by a tetanic spasm and due to a manganese deficiency in the maternal diet has also been reported.

Goiter.[9] A deficiency of iodine in the ration affects the functioning of the thyroid gland, causing an enlargement known as goiter. The thyroid gland increases to many times the normal size. Histological examinations of the enlarged thyroid glands show an absence of colloid and a hyperplasia of the living cells of the follicle.

Iodine might be deficient, especially if the amounts of fish meal and other marine products are limited. It has also been observed that soybeans have a goitrogenic effect. The addition of 0.5 per cent of iodized salt to poultry rations is adequate to meet the iodine requirements.

Anemia.[10] A deficiency of iron or copper in poultry rations results in anemia. Certain vitamins or organic factors, such as folic acid, have been reported as also being essential for the prevention of anemia in growing chicks.

Probable Mineral Deficiencies. The ration must contain a suitable inorganic content. However, the practical poultryman is concerned only with the minerals that might be deficient in his ration. If a good ration, made up of natural feeding stuffs, is fed, the minerals that are likely to be found deficient are sodium, chlorine, calcium, and phosphorus.

The sodium and chlorine are furnished by adding common salt. Usually one-half to one per cent is included in the ration. Calcium for eggshell formation is best supplied in the carbonate form. Oyster shells and limestone will furnish this mineral. Where wheat by-products, meat scraps, and milk are used, there will usually be enough phosphorus. When necessary to supply phosphorus, bone meal, dicalcium phosphate, or defluorinated rock phosphate are added to the ration.

Manganese might sometimes be deficient. Only small amounts of the manganese salts will supply the need. A common practice of commercial mixers is to add about one quarter pount of manganese sulphate to each ton of mash.

Possible Mineral Excesses. Where minerals are necessary, they usually need to be added in only comparatively small quantities. Some are detrimental in large amounts. For instance, too much calcium[11] will retard growth and increase mortality in chicks and decrease production and hatchability. In the body certain minerals are balanced by other minerals, and excesses of some might use up the others so as to cause a deficiency. This is true of phosphorus which will combine with manganese.

Excess magnesium in the chick ration has resulted in deformed bones.[12] The use of dolomite limestone containing a high percentage of magnesium[13] has caused egg production to decrease and the shells of the eggs to become progressively thinner. The hens also developed diarrhea and became extremely irritable and easily frightened.

An excess of fluorine[14] has resulted in retarded growth in young chicks and lower egg production and loss of weight in laying hens.

An excess of selenium is also harmful.[15] It has produced retarded growth, ruffled feathers, and irritability in chicks and delayed and reduced egg production and poor hatchability in hens. Many of the embryos which failed to hatch were deformed.

Thus minerals require as much good judgment and as many precautions in their use as other constituents of the ration.

Mineral Mixtures. In general, the use of complex mineral mixtures is not suggested. On the other hand, it is recommended that additions of minerals be specific for definite deficiencies and that such minerals be used singly rather than in combinations. The addition will depend upon the deficiency, and hence each ration is likely to require its own mineral mixture addition.

Grit.[16] Grit may function as a source of minerals when it is furnished in soluble form. It functions as a grinding material only when insoluble. Limestone grit, oyster shells, and rock phosphate furnish minerals but also act as grinding agents. Their life as grinding agents is relatively short. Hens and chicks will benefit by the presence of a grinding material in the gizzard, especially when coarse materials are consumed. Larger and heavier gizzards have been reported for birds receiving insoluble grit. Grit apparently is not necessary when the ration is all mash. When grain is fed, the presence of a grinding material will increase the feed efficiency. The common practice is to supply a grinding material such as grit when grain and other coarse materials are consumed.

CARBOHYDRATES. The carbohhydrates are organic compounds composed of carbon, hydrogen, and oxygen. They are formed in the plant by photosynthesis as follows: $6CO_2 + 6H_2O$ + energy from the sun = $C_6H_{12}O_6 + 6O_2$. The monosaccharides or simple sugars include glucose, fructose, and galactose. The disaccharides or compound sugars comprise such compounds as sucrose, maltose, and lactose. The polysaccharides include such substances as the hemicelluloses, cellulose, dextrin, starch, and lignin.

From the feeding standpoint, the carbohydrates consist of nitrogen-free extract (N.F.E.) and fiber. The nitrogen-free extract consists mainly of starches, sugars, and a large part of the hemicelluloses. It makes up the so-called soluble portion of the carbohydrates. The fiber, the woody portion or cellulose tissue of the plant, consists of cellulose, hemicellulose, and lignin. In the fowl, fiber is digested, if at all, to only a slight degree. It, therefore, should not be fed in large amounts.

Carbohydrates are used by the body as a source of heat and energy. Any excess may be stored in the body as fat. The yolk of the egg, which is largely fat, may be derived from excesses of carbohydrates in the ration.

FATS. Lipids (fat and fat-like substances) are organic compounds soluble in such organic solvents as ether, chloroform, or benzine, and composed of glycerol and fatty acids (commonly stearic, palmitic, and oleic acids). Like carbohydrates, they contain the three elements carbon, hydrogen, and oxygen. They function the same as carbohydrates in that they serve as a source of heat and energy in the body and of fat in the body and the egg yolk. Fats, however, are so constructed as to liberate more heat upon burning or when digested. They contain approximately two and one fourth times as much energy as carbohydrates. Therefore, less fat is required to serve the same function.

Recent evidence indicates that chickens also have a specific requirement for certain of the unsaturated fatty acids[17] which would then become essential fatty acids.

In the feeding of poultry, carbohydrates, rather than fats, are fed as the principal source of energy. This is true because carbohydrates are usually cheaper and are very easily digested, absorbed, and transformed into fat. Feeds which contain large amounts of fat are likely to become rancid in hot weather, and rancid feed may be injurious to poultry by oxidizing some of the vitamins. Small amounts of fat, however, are desirable since they are carriers of the fat-soluble vitamins and aid in their absorption.

Most of the feeds used in poultry rations do not carry too much fat. Those feeds which are high in fat, such as flaxseed, cottonseed, sunflower seed, and soybeans, are usually extracted for their oil and the remaining meal used for animal feeding.

PROTEINS. Proteins are complex organic compounds made up chiefly of amino acids, present in characteristic proportions for each specific protein. This nutrient always contains carbon,

hydrogen, oxygen, and nitrogen, and in addition usually contains sulfur and frequently phosphorus. Proteins are composed of many simpler units called amino acids, of which twenty-three are known. The amino acids are sometimes referred to as the building stones of the proteins. The value of protein depends upon its amino acid composition. The feed proteins are broken down into amino acids by digestion. They are then absorbed and distributed by the blood stream to the body cells which rebuild these amino acids into body proteins.

Essential Amino Acids. Certain of the amino acids are called essential amino acids, because they are indispensable to the animal and cannot be synthesized by the body, and hence must be included in the diet. When the protein contains all the necessary amino acids and will maintain the animal and promote normal growth, it is called a complete protein. Some proteins may be deficient in one or more of the essential amino acids. Such proteins are sometimes called incomplete proteins. A combination of incomplete proteins may supply proteins of good quality in a ration because of their supplementary effects. The deficiency of amino acids in one protein is made up for by the presence of these amino acids in the other protein or proteins.

Amino Acids. The known amino acids which are involved in nutrition are: tryptophan, lysine, methionine, histidine, leucine, isoleucine, phenylalanine, threonine, valine, arginine, glycine, cystine, alanine, norleucine, tyrosine, serine, aspartic acid, glutamic acid, hydroxyglutamic acid, proline, hydroxyproline, iodogorgoic acid, and thyroxine. Of these, the first eleven have been shown to be essential for chickens. Methionine and cystine are sulfur-bearing amino acids. Thyroxine and iodogorgoic acid contain iodine. Cystine can substitute for part of the methionine. Glycine or arginine are precursors of creatine and, with cystine, are essential for feather development and also prevent a certain type of paralysis.[18] Lysine has been reported as being needed for feather pigment formation in turkeys[19] (Fig 2).

Proteins are widely distributed in plants, which build them up from simple sources in the soil and air. Proteins are the main constituents of animal tissues, which must derive them directly or indirectly from plant tissues. Animal protein feeds are generally of higher quality than vegetable protein feeds because they contain a larger amount of the essential amino acids as well as other necessary nutrients.

Moderate heat treatment improves the quality of soybean protein, whereas prolonged heat treatment decreases the quality.

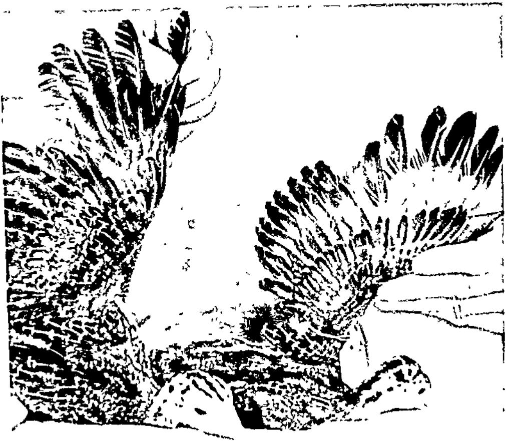

Fig. 2. White-feather syndrome caused by feeding a lysine-deficient diet (right). 7-week old poults. (Courtesy Ontario Agricultural College.)

This is probably due largely to the effect of the heat treatment upon the availability of such amino acids as methionine, lysine, and tryptophan.

Requirements for Proteins. Birds require proteins in their ration for the construction of body tissues. Tissues which are mainly protein are muscles, nerves, cartilage, skin, feathers, and beak. The albumen of the egg is also largely protein. Protein may also enter into the composition of enzymes, hormones, and vitamins.

Proteins also have definite physiological effects. One of these effects is the specific dynamic action of proteins, in which the cell activity is stimulated, and the heat production thereby increased. The animal can take care of a considerable excess of protein, but sometimes overfeeding of proteins may affect the kidneys.

The prime function of protein in the animal body is to supply the amino acids. Any amino acids that are left over, after the requirement has been met, are destroyed in the liver. In this process, a part of each amino acid is turned into fuel, and the remainder is excreted by the kidney. Hence proteins in the ration can also serve as a source of energy. However, because proteins are usually expensive, carbohydrates or fats are more economical to use as a source of energy.

Continued health and physiological efficiency are possible ove a wide range of protein intake. However, with proteins, perhaps as with no other nutrient, the body is on continual guard against possible deleterious action of its intermediate digestion products, bacterial end products, and intermediate metabolites.

VITAMINS. Vitamins are those substances which occur in natural feeds in relatively small amounts but are absolutely necessary for growth, reproduction, and the maintenance of health. A prolonged deficiency of many of the vitamins will develop a nutritional deficiency disease.[20] The symptoms of some of these are characteristic so that an experienced observer has little difficulty in recognizing them. Some of these deficiency diseases have been known throughout medical history, such as scurvy, rickets, beriberi, and pellagra.

Formerly the only method of distinguishing the different vitamins was to observe the effects of rations, deficient in one of these nutritive factors, on rats, guinea pigs, pigeons, chickens, and other animals. Until recently, very little has been known regarding the chemical or physical properties of the vitamins. However, in recent years a number of these vitamins have been isolated chemically and synthesized. At the present time, many of the vitamins can be distinguished by chemical and physical properties, as well as by biological and bacteriological assay.

Chemically the vitamins include a variety of compounds. However, they are usually classified as fat-soluble and water-soluble vitamins. Unlike the other classes of nutrients, which are comparatively stable chemical compounds, many of the vitamins are more or less unstable. They are destroyed by exposure to air, heat, light, enzymes, acids, and alkalis Because of this instability, care must always be taken to insure an ample supply of vitamins in poultry rations. An excess can in certain cases be stored in the animal tissues and in the egg Many of the pure vitamins have crystals of characteristic color and shape.

A number of different vitamins are recognized At first, they were named by letter or after the effect upon the animal. Where

the chemical name is known, this nomenclature is preferred. Besides the known vitamins, the existence of others is strongly suspected, as several investigators have reported the presence of substances in feedstuffs, which are vitamin-like in nature and possess characteristics that fail to correspond to those of the known vitamins.

Vitamin A.[21] Vitamin A is necessary for maintenance of healthy epithelia in various parts of the body as in the eyes, respiratory tract, and intestinal tract. In vitamin A deficiency, the secretions of the intestinal mucous glands, the tear glands, and the salivary glands fail. Certain tissues, such as the margins of the eyelids, become granular. An opaque appearance, caused by keratinization of the third eyelid, may be observed. Infection may set in and, where it attacks the eyes, a viscous

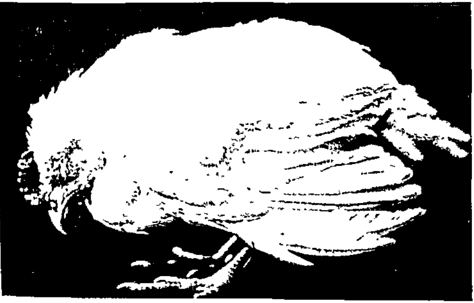

Fig. 3. Vitamin A deficiency. Note the exudate from the eye and the general ruffled appearance. (Courtesy Cornell University.)

fluid is produced which causes the eyelids to stick together (Fig. 3). In some animals, a white film gathers over the center of the eyeball and blindness results. When these symptoms occur, the disease is generally called xerophthalmia. Vitamin A is also necessary for the normal adaptation of the eye to darkness. A low intake of this vitamin results in night blindness.

Pathological lesions, observed on autopsy, are confined largely to the mucous membranes of the mouth, pharynx, esophagus, and

respiratory and urinary systems. Creamy white pustules are often found on the roof of the mouth and along the esophagus, sometimes extending into the crop. Urates accumulate in the ureters and in the kidney tubules, so that these organs are enlarged and creamy white in color. This urate accumulation is easily detected on gross examination because of its whitish appearance.

In mature fowl, the symptoms noted for chicks may develop much more slowly, but the eye disorder often becomes more acute. A cheesy exudate from the eyes often is observed, as well as a sticky discharge from the nostrils. The disease is sometimes referred to as nutritional roup because of its similar appearance to roup, a true disease due to other agents. Egg production and hatchability are markedly reduced. It has been reported that blood-spot incidence decreased as the level of vitamin A was increased.

On a severely deficient chick diet, the symptoms of vitamin A deficiency may appear in 2 to 3 weeks. Growth is markedly retarded, the chicks show general weakness, emaciation, and ruffled plumage. Afflicted birds walk in a peculiar weaving or zigzag manner and finally are unable to stand. After this, death soon occurs.

The symptoms of a vitamin A deficiency in turkey poults are, in general, similar to those described for chicks, but are usually much more acute.

Vitamin A, a fat-soluble vitamin, has been chemically identified but not yet given a chemical name. Plants contain precursors, that is, substances that are transformed into the vitamin in the animal body. The pigments carotene and cryptoxanthin are precursors of vitamin A. Carotene is associated with yellow pigments in plants. When vitamin A and carotene are exposed to the air, particularly at warm temperatures, they are gradually destroyed. Hence vitamin A may be lost during storage. The chief sources of vitamin A are fish oils, some animal fats, green grasses, properly dried grasses, yellow corn, and synthetic vitamin A.

Vitamin B Complex. The original vitamin, known as vitamin B, has been found to be composed of a large number of vitamins or vitamin-like factors. This condition has made the terminology confusing. Some of these factors have been isolated and recognized; others are still not so well known

Vitamin B_1 (Thiamin).[22] Vitamin B_1, known chemically as thiamin, is necessary for maintenance of the appetite and preserva-

tion of the health of nervous tissue. Vitamin B_1 deficiency results in loss of appetite, emaciation, general weakness and inability to stand, frequent convulsions, and finally death. It is known technically as polyneuritis or beriberi. In the acute stages of polyneuritis, the head may be drawn over the back (Fig. 4).

Fig. 4. Vitamin B_1 deficiency (polyneuritis). Note typical head retraction. (Courtesy Cornell University.)

Thiamin is found in the germ and bran of all grains, as well as in yeast, alfalfa, green pasture, and milk products. Hence it is plentifully supplied in every ordinary poultry ration and does not need to be fed in extra quantities by providing special supplements. It is soluble in water and alcohol and is very stable. Exposure to air and moderate dry heat do not destroy it.

Riboflavin (Vitamin B_2 or G). Vitamin B_2 (G), known chemically as riboflavin, is required for the formation of an enzyme present in all living cells. It is necessary for growth, preserves the health of the peripheral nerves, prevents leg paralysis (curled toe paralysis), and is essential for hatchability.

A lack of riboflavin in the diet of young chicks results in diarrhea, retarded growth, and paralysis of the legs, sometimes called nutritional leg paralysis.[23] It involves the legs and feet and occurs in two stages, a preliminary stage which is curable

and an acute stage which is incurable. Nutritional paralysis is characterized by chicks suddenly walking on their hocks, with toes curling inward. Otherwise the chicks appear to be in excellent health. The disease ordinarily appears when the chicks are 3 to 4 weeks old. There may be some trembling of the legs (Fig. 5). Chicks receiving rations only partially deficient in this factor often recover spontaneously. The severe cases of the

Fig. 5. Riboflavin deficiency in a young chick. Note the position of the hocks, with the toes curled inward. (Courtesy Cornell University.)

paralysis show very marked hypertrophy and softening of the brachial and sciatic nerves, which are usually discernible by inspection. The symptoms are most pronounced and most often observed in the sciatic nerves. These nerves occasionally reach a diameter four to five times normal size.

In breeding birds[24] a deficiency of riboflavin results in poor hatchability. The requirement for hatchability is considerably higher than for egg production and maintenance of health. The embryos that fail to hatch as a result of a riboflavin deficiency are dwarfed, show a high incidence of edema, degeneration of the Wolffian bodies, and a characteristically defective down development, termed clubbed down. On a ration moderately deficient in riboflavin, many embryos die during the second week of incubation. The mortality reaches a peak at about the eleventh day of development.

Riboflavin is a water-soluble vitamin, is fairly stable to heat, but is destroyed by irradiation.

The chief sources of riboflavin for poultry rations are milk products, yeast, liver, alfalfa meal, cereal grass, green pastures, and by-products of the fermenting and distilling industries.

Pantothenic Acid. Pantothenic acid, known also as the anti-dermatitis vitamin or the filtrate factor, preserves the health of the skin and spinal cord. A pantothenic acid deficiency in young chicks[25] results in retarded growth and extremely ragged feather

Fig. 6. Pantothenic acid deficiency. Note the lesions at the corners of the mouth, on the eyelids, and feet. (Courtesy Cornell University.)

development (Fig. 6). Within 12 to 14 days, a pellagra-like syndrome develops. The eyelids become granular and stick together as a result of a viscous exudate. Crusty scabs appear at the corners of the mouth and around the vent. Dermatitis of the feet, involving thickening and fissuring of the skin on the bottoms of the feet, causing an awkward gait, is sometimes observed in pantothenic acid deficiency, though the lesions are seldom as severe as those brought about by a biotin deficiency. Liver damage and changes in the spinal cord may be seen on post-mortem examination.

Lesions in adult fowls, similar to those of growing chicks, have usually not been observed although a deficiency of pantothenic acid results in lower hatchability.[26]

Pantothenic acid is supplied chiefly by milk products, yeast, liver, cane molasses, peanut meal, distillers' solubles, alfalfa meal, green pasture, and grains and grain by-products.

Vitamin B_6 (Pyridoxine). Vitamin B_6, known chemically as

pyridoxine, is necessary for growth and maintenance of appetite and the prevention of a certain type of convulsions.[27] Chicks fed a pyridoxine-deficient diet show a small initial gain, then cease to grow, or grow very slowly. Some chicks show abnormal excitability and somewhat jerky convulsive movements. Chicks suddenly may run about aimlessly, often flopping their wings and keeping their heads down. Later, convulsions occur. During these convulsions, the chick may rest on its breast, raise its feet off the floor, and flop its wings. Chicks may fall on their sides, roll over on their backs, and rapidly paddle their feet. The head often jerks up and down or retracts, as in polyneuritis, and sometimes moves convulsively in an up-and-down movement with the neck distended or twisted. Complete exhaustion follows one of these convulsions, which are frequently fatal (Fig. 7).

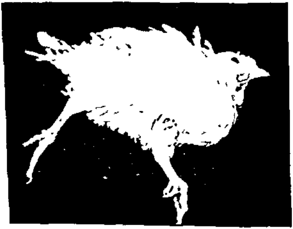

Fig. 7. Pyridoxine deficiency. Note loss of control of the legs and the head retraction. (Courtesy Cornell University.)

Pyridoxine deficiency in mature birds is characterized by loss of appetite, followed by rapid loss of weight, and death. Egg production and hatchability are reduced markedly.[28]

The chief sources of pyridoxine in the ration are grains, wheat by-products, rice by-products, yeast, liver, cane molasses, distillers' solubles, alfalfa meal, and cereal grass.

Vitamin B_{12} (Cobalamin).[29] Vitamin B_{12} is necessary for growth, feather development, and hatchability. Hemoglobin and red cell counts on vitamin-B_{12}-supplemented embryo blood were reported higher than on blood of B_{12}-deficient embryos. Vitamin

B_{12} also appears to be connected with protein metabolism. The *response of "animal protein factor" supplements was due chiefly* to their content of this vitamin.

Vitamin B_{12} is supplied by special fermentation products, liver, fish meal, fish solubles, meat scrap, and milk products.

Niacin (Nicotinic Acid). Niacin, formerly known as nicotinic acid, is necessary for growth and feather development. It prevents inflammation of the mouth cavity, esophagus, and crop, and scaly dermatosis of the skin and feet.[30]

A deficiency of niacin in the diet of the chick results in "Blacktongue," a condition characterized by inflammation of the tongue and mouth cavity. Beginning when the chick is about 2 weeks old, the entire mouth cavity of the deficient chicks, as well as the upper part of the esophagus, become distinctly inflamed with a deep red color, in contrast to the normal pink of

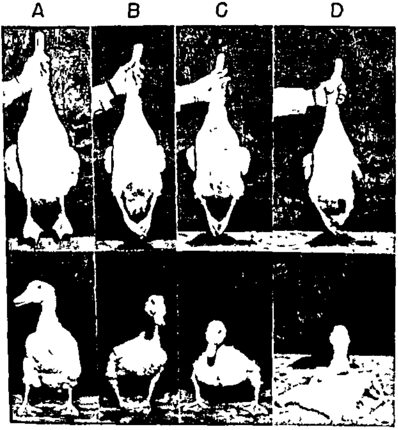

Fig. 8. Bowed legs in ducks due to a niacin deficiency. A = normal, B = bowed, C = very bowed, D = crippled. (Courtesy Cornell University.)

the healthy chick. Growth is retarded and feed consumption is reduced. Poor feather development and occasionally scaly dermatitis of the feet and skin are also observed.

Bowed legs in ducks caused by muscle deterioration has also been attributed to a niacin deficiency[31] (Fig. 8).

Pellagra in human beings and a similar condition in dogs, known as blacktongue, are prevented by niacin.

The chief sources of niacin in the ration are liver, yeast, wheat by-products, rice by-products, peanut meal, distillers' solubles, corn gluten feed, cereal grass, barley, and synthetic niacin.

Biotin. Biotin (formerly sometimes called vitamin H) is necessary for growth and hatchability. It is also involved in the prevention of perosis and a dermatosis similar to pantothenic acid deficiency.

In biotin deficiency in chicks[32] lesions first appear in about 3 weeks, *although considerable variation in the time of appearance* has been noticed. The bottoms of the feet become rough and calloused and may be severely affected before mandibular lesions are apparent. As the syndrome progresses, the entire bottom of the foot becomes encrusted, and hemorrhagic cracks appear. The toes may become necrotic and slough off, but the top of the foot and the legs usually show only a dry scaliness. The mandibular lesions, which first appear in the corners of the mouth, spread to include the area around the beak, and the eyelids eventually become swollen and stick together (Fig. 9). In contradistinction to these symptoms, the lesions in pantothenic acid deficiency are first evident in the corners of the mouth and eyes, and only in extreme cases do the lesions of the feet become so severe.

Biotin has been reported to be one factor necessary for the prevention of perosis[33] in chicks and in turkeys. Turkey poults exhibit symptoms very similar to those described for chicks when fed a biotin-deficient ration.

Feeding mature fowl[34] a biotin-deficient ration causes reduced hatchability while egg production is not adversely affected, indicating that the requirement for the production of hatching eggs is much higher than necessary for maintenance of good health and egg production. In hens, no dermatitis similar to that of chicks fed biotin-deficient rations has been observed.

The chief sources of biotin in the ration are grains, liver, yeast, cane molasses, alfalfa meal, green pasture, and distillers' solubles.

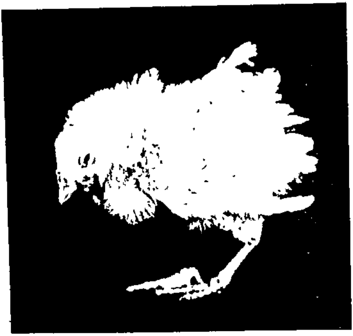

Fig. 9. Biotin deficiency. Note lesions on the feet and at the corner of the mouth. (Courtesy Cornell University.)

Choline.[35] Choline is necessary for growth, bone development, and egg production. A lack of choline in the diet of young chickens and turkeys results in retarded growth and perosis. In ducklings a choline deficiency has also been reported as causing fatty infiltration of the liver. Choline deficiency in mature birds has been reported to result in increased mortality and lowered egg production, with an increased abortion of egg yolks from the ovary.

Choline is supplied by grains, wheat by-products, liver, meat scraps, fish meal, milk products, soybean meal, peanut meal, distillers' solubles, and choline concentrates.

Folic Acid[36] (Pteroylglutamic Acid, Folacin). Folic acid is necessary for growth, maintenance of weight, hemoglobin formation, egg production, and hatchability. It is also involved in good feather formation and the prevention of perosis. In turkeys and geese its absence will cause cervical paralysis (Fig. 10).

The chief sources of folic acid are soybean meal, peanut meal, yeast, distillers' solubles, alfalfa meal, cereal grass, green pasture, and liver.

Other Organic Factors. Inositol,[37] which has been reported necessary for growth, is present in grain, wheat by-products, alfalfa meal, milk products, yeast, and liver.

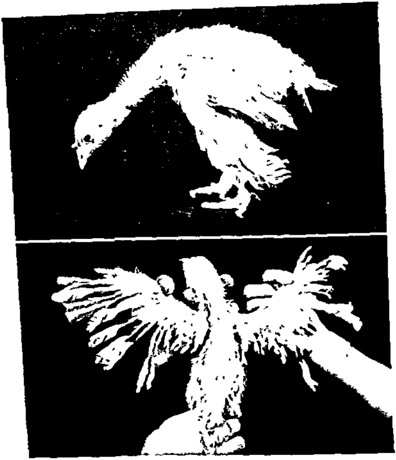

Fig. 10. Folic acid deficiency. Top, cervical paralysis in a turkey. Bottom, poor feathering in a chick. (Courtesy Cornell University.)

Glucuronic acid,[38] which has been reported necessary for growth, is found in oats, wheat by-products, liver, meat scraps, and fish meal.

The antigizzard erosion factor[39] has not been identified chemically. It prevents crater-like lesions and eroded areas on the secreted lining of the gizzard. It is present largely in alfalfa meal, green grass, wheat by-products, oats, and fresh milk. Cholic acid of the bile is an effective preventive of gizzard lesions.

Vitamin C (Ascorbic Acid). Vitamin C is not needed in the poultry diet. Apparently birds are able to make this substance

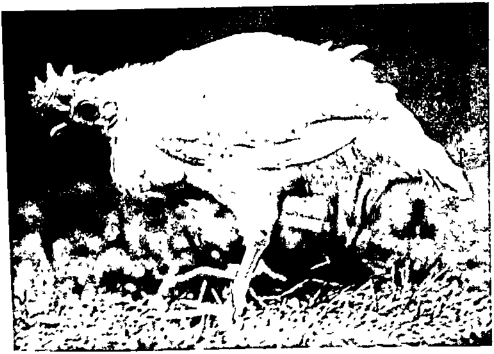

Fig. 11. Vitamin D deficiency (rickets). Note the ungainly manner of balancing the body and initial swelling of the hock joint. (Courtesy Cornell University.)

in their own bodies. In those species which require vitamin C a deficiency of it will produce scurvy.

Vitamin D. Vitamin D is necessary for calcium amd phosphorus utilization. It prevents rickets, the laying of thin-shelled eggs, and failure in egg production and hatchability.

A lack of vitamin D, in the absence of direct sunlight, results in the nutritional deficiency rickets.[40] The chicks are retarded in growth, show a disinclination to walk, or walk with a lame, stiff-legged gait, and have an ungainly manner of balancing the body (Fig. 11). The chicks appear generally unthrifty. In this disorder, an upset occurs in the mechanism involving the absorption and retention of calcium and phosphorus, as a result of which these minerals are not deposited in normal amounts in the bony structure of the body (Fig. 12). Abnormal bone development may be detected most readily in the legs and at the junction of the ribs on the side of the breast. The spinal column may be curved, and the sternum usually shows acute lateral bending or depression. Enlargement of the hock joints and beading of the rib ends become apparent. The beak is soft and rubbery and may be easily bent.

Fig. 12. Vitamin D deficiency Left, poor skeletal formation. Note beading and bending of the ribs, spinal curvature, and crooked breastbone Right, poor bone formation. Top, rachitic bone. Note wide band of cartilage and lack of calcification. Bottom, normal bone. (Courtesy Cornell University.)

In mature laying birds, the first symptom of a vitamin D deficiency is the laying of thin-shelled eggs, followed very shortly by decreased egg production. The breast bone becomes soft and rubbery, and the bones of the legs and wings become fragile and easily broken. Birds may lose, temporarily, the use of their legs and squat in a "penguin-like" manner, a symptom which sometimes has been called "egg paralysis." Hatchability is reduced markedly.

The symptoms of a vitamin D deficiency in turkeys are very similar to those described for chickens.

A deficiency of vitamin D has been reported as causing black pigmentation in buff feathers.[41]

Vitamin D is a fat-soluble vitamin, somewhat more stable than vitamin A. However, it is slowly affected by heat and exposure to air. There are a number of different forms of vitamin D. Vitamin D_3 or activated 7-dehydrocholesterol is the form which is most effective for chickens. This is the form found in fish liver oils and irradiated animal sterols. When incorporated in the ration, vitamin D is supplied usually as fish oils or activated animal sterol.

Vitamin D intended for poultry use was formerly expressed as A.O.A.C. (Association of Official Agricultural Chemists) chick units which represented the activity for chicks of 1 unit of vitamin D in U.S.P. Reference Cod Liver Oil. The International unit was used to express vitamin D potency for man and four-footed animals. The A.O.A.C. unit measured vitamin D_3. The U.S.P. unit measured vitamin D_2. These could not be used interchangeably because the effectiveness of these two forms was considerably different for poultry. Now vitamin D unitage has been standardized by an international committee. The International or U.S.P. unit for man and four-footed animals is the same as the International chick unit for poultry. They represent the activity of 0.025 microgram crystalline vitamin D_3 (activated 7-dehydrocholesterol). In order to interpret A.O.A.C. values in terms of the International chick unit, the A.O.A.C. values must be reduced by 25 per cent.

Vitamin D is perhaps the most peculiar of the vitamins since it may be supplied by certain light rays.[42] These rays are usually referred to as the ultraviolet rays or ultraviolet light. They are rays of comparatively short wave length, found in sunlight, and may be produced artificially by mercury vapor or carbon arc lamps. They synthesize the vitamin in the body by activating cholesterol in the skin to the active form of the vitamin.

Vitamin E. Vitamin E, known chemically as alpha-tocopherol, preserves the health of the reproductive organs and of the cerebellum and cerebrum of the brain. It prevents nutritional encephalomalacia (crazy chick disease), failure in hatchability, and loss of fertility in males.[43]

A lack of vitamin E in the ration of growing chicks results in the condition known as nutritional encephalomalacia. Chicks afflicted with this deficiency disease suddenly become prostrated, lying with legs outstretched and spastic, and toes flexed. The head is retracted and often twisted laterally. Before the chicken becomes completely prostrated, its gait and other movements are often incoordinate (Fig. 13). Upon autopsy, lesions are found

Fig 13. Vitamin E deficiency in the chick. Note prostrated chick with retracted head (Courtesy Cornell University.)

in the cerebellum and sometimes in the cerebrum In many chicks, the chronic reddish or brownish areas on the surface of the cerebellum can be seen by inspection. Under some conditions, vitamin E deficiency results in subcutaneous edema and edema of the heart and pericardium.

In mature fowls, a prolonged vitamin E deficiency results in sterility in the male and reproductive failure in the female. Degenerative changes in the testes of the male may occur, resulting in permanent sterility In females egg production apparently is not affected by a vitamin E deficiency, but hatchability is reduced markedly. During incubation the rate of growth and dif-

ferentiation are slow, and many embryos die during the first 2 days of development because of a circulatory failure. A definite critical period in the development of the embryo occurs about the fourth day.

In poults, a deficiency of vitamin E results in the condition known as nutritional myopathy. This condition is characterized by lesions in the muscular wall of the gizzard. These lesions appear as circumscribed gray areas which often are of firmer texture than normal muscle and in some cases suggest scar tissues. It may also be involved in the production of enlarged hocks.

Vitamin E, a fat-soluble vitamin, is very stable. It is found largely in grains, wheat by-products, alfalfa meal, green pasture, cereal grass, and wheat germ oil. It is usually present in these feeds to such an extent that the fowl's needs seem to be completely supplied by ordinary rations.

Vitamin K. Vitamin K, which has been chemically identified but not named and is also known as the antihemorrhagic vitamin, is necessary to preserve the clotting power of blood.[44] It does prevent death from hemorrhage.

A lack of vitamin K greatly delays the clotting time of the blood. Chicks fed a deficiency ration may bleed to death from any injury or bruise which causes rupture of blood vessels. Hemorrhages may occur subcutaneously, intramuscularly, intraperitoneally, or in any part of the chick's body (Fig. 14). The hemorrhages vary in size and appear to be the only symptom of the deficiency.

In mature birds, vitamin K may be synthesized to some extent, as they do not seem to be subject to the acute deficiency. It has been shown, however, that laying birds fed a diet low in vitamin K produce eggs low in vitamin K. When these eggs are incubated, chicks are hatched which have very low reserves of vitamin K, with an accompanying prolonged blood-clotting time. Chicks may bleed to death from an injury such as may result from wing banding.

Vitamin K is a stable, fat-soluble vitamin. It is found chiefly in alfalfa meal, cereal grass, green pasture, meat scrap, and fish products.

Other Vitamins. A number of other vitamins have been reported, but their importance in poultry feeding has not yet been shown. They might include some of the other B vitamins, factor S,[45] the whey factor,[46] the grass juice factor,[47] and perhaps others.

Recent reports from a number of experiment stations indicate

Fig 14. Vitamin K deficiency Note general hemorrhages (Courtesy Cornell University)

unidentified factors[48] in such ingredients as alfalfa, corn molasses (hydrol), dried distillers' solubles, dried yeast, fish products (including fish meal and fish solubles), liver, meat scrap, and peanut meal

Requirements for Vitamins. The ration must contain sufficient vitamins. There is a difference in the requirements of different species for the various vitamins. In general, the principles, from a qualitative standpoint, can be applied from one species to another. However, quantitatively, the various species differ, and the actual requirements must be determined by using the species in which one is interested. The quantitative requirements, therefore, for chickens should be determined with chickens as the experimental animal. The quantity of any of the vitamins required varies with the age, sex, and condition of the birds. Chicks and laying hens usually have a larger vitamin requirement than do nonproducers. Generally, too, the requirements for hatchability are greater than the requirements only for egg production. Also turkeys differ from chickens in their needs.

ANTIBIOTICS

One of the most spectacular recent developments in nutrition science is the discovery that antibiotics[49] have growth-stimulating properties when fed to chickens, turkeys, and swine. Few nutritional discoveries have been so quickly and universally applied to feeding practice. The finding came as a result of the use of by-products from antibiotic production as sources of vitamin B_{12}.

It had been repeatedly shown that a ration whose protein is derived from vegetable source will not produce as good growth or hatchability as a ration containing animal proteins. Much interest was therefore shown in the so-called APF (animal protein factor) supplements. This name was derived from the fact that these materials were added to rations from which the animal protein feeds were removed and this probably supplied a factor or factors furnished by animal protein concentrates. They usually supplied vitamin B_{12} and as yet unidentified factors. After the discovery of vitamin B_{12} it was shown that one big difference between these rations is that the vegetable protein diet contains much less of this vitamin. It was also shown that by-products of antibiotic production and other fermentation products were good sources of vitamin B_{12} and could be used for this purpose to supplement rations whose protein was largely or entirely derived from vegetable source.

After synthetic vitamin B_{12} became available it was observed that at times the feeding of antibiotic by-products produced

greater growth-promoting activity than could be attributed to their vitamin B_{12} content. It was suspected therefore that some other factor, probably the antibiotic, was producing the extra growth stimulus. This was confirmed by the use of pure antibiotics such as penicillin, aureomycin, terramycin, bacitracin, streptomycin, and others when added to rations containing sufficient vitamin B_{12} and other nutrients.

GROWTH STIMULATION. The increase in growth rate obtainable by antibiotic feeding varies with the type of animal, being greatest for turkeys, somewhat less for chickens and goslings, and least for ducks. The differences are greatest in the early growth period and decrease with age. Increases in early growth rate (during the first month) for chickens has been reported to be about 10-15 per cent. Failure to differentiate clearly between growth response due to vitamin B_{12}, or other essential nutrients, and that due to antibiotics (when the source of the antibiotic was the by-product) has led in some cases to an exaggerated concept of the antibiotic effect.

The feeding of antibiotics has had a growth-stimulating effect with rations containing animal protein feeds as well as those composed entirely or largely of protein from vegetable source. The fact that the relative stimulation is greater on an all-vegetable ration indicates that the antibiotic tends to spare or reduce the requirement for some unidentified nutrient associated with animal proteins. Actually best growth is generally obtained when an antibiotic is added to a ration which contains animal protein and which is complete in all known respects.

If the antibiotic supplement is withdrawn during the period of greatest growth stimulation, a growth retardation usually occurs which largely cancels out the weight advantage obtained up to that time. In no case has the retardation been sufficient to result in slower growth than the corresponding control groups which never received antibiotic supplementation. In broiler production, where weight gains are of major importance, it appears advisable to continue antibiotic supplementation throughout the growth period.

EFFECT ON FEED EFFICIENCY. Research on the effect of antibiotic feeding on the efficiency of feed utilization shows that a small improvement in the efficiency of feed conversion (pounds of feed required to produce a pound of meat) accompanies the growth stimulation; as the growth stimulation disappears, the improvement in feed utilization likewise tends to disappear. It would appear, therefore, that the efficient use of antibiotics

covers only the period during which the actual growth stimulation is evident, and that the prolonged use of antibiotics beyond this period does not produce any return to the feeder.

AMOUNT NEEDED. Levels as low as 1 to 2 grams of some pure antibiotics per ton of feed have produced effective growth stimulation, although considerably larger amounts (50 or more grams per ton) have no harmful effects. Lower levels of an antibiotic have produced as effective stimulation as higher levels in experiments with the four major antibiotics generally used (penicillin, aureomycin, terramycin, and bacitracin). In the main no advantage is shown by a combination of antibiotics. The level of use of a specific antibiotic should be in accord with the manufacturer's recommendations.

OTHER EFFECTS. Besides the strictly nutritional effects, as expressed in increased growth, antibiotics have been shown to be effective in preventing such conditions a necrotic enteritis in swine. Hence there may also be some therapeutic value due to the feeding of the antibiotic. This might account for those reports which indicate lower mortality, generally better health or condition, greater uniformity, better feathering, and consequently improved performance and appearance. It might also account for those reports which showed greater benefit from the use of antibiotics under field conditions with the birds managed on the floor or ground as compared with birds kept on wire or in batteries under good conditions of management. Antibiotics are also effective in the control of specific diseases.

HENS. Antibiotics for laying and breeding hens are generally ineffective, having little or no effect upon egg production, hatchability, body weight, feed consumption, egg weight, egg quality, sexual maturity, or mortality.

MECHANISM OF EFFECT. Most investigators believe that the antibiotics exert their nutritional effect through changing the types and numbers of intestinal microorganisms. This might be accomplished by (1) suppression of inhibitory or "toxin-producing" microorganisms, (2) stimulation of microorganisms which manufacture known or unidentified vitamins which can subsequently be used by the host animal, (3) suppression of microorganisms which compete with the host animal for certain essential food nutrients, (4) suppression of "disease level" by eliminating pathogenic organisms from the intestinal tract.

Although each of these hypotheses is plausible, no single explanation seems to serve all cases, and it is not unlikely that several mechanisms may operate in various situations. A part

of the growth-stimulating effect may be accounted for by appetite stimulation resulting in greater feed intake. The growth-stimulating effect of antibiotics is most spectacular when observed under conditions which greatly retard the growth of animals fed the usual type of practical rations.

In general, the levels of antibiotics used in practical poultry feeding are too low to have a specific effect on recognized infection, or on the intestinal microorganism population. When higher levels are fed, reported research indicates correlated changes in intestinal microorganisms; these studies, however, have not clearly shown whether the shifts in intestinal flora are responsible for any or all of the growth-stimulating effect of antibiotics.

GROWTH PROMOTERS

Growth stimulation has also been accomplished in other ways. Arsonic acid derivatives[50] have been reported to produce growth stimulation. Detergents[51] or surface acting agents, called "surfactants," have also been reported as being effective in this respect. Results, however, have not been consistent. Why they produce the results has not been explained.

Free methionine added to the ration in relatively small amounts has in some cases produced added growth and increased the efficiency of feed utilization.[52]

INTERRELATIONSHIPS OF DIETARY FACTORS

Nutrition workers have long recognized the existence of interrelationships of dietary factors. More of these are becoming apparent, and they frequently help to explain unexpected results.

One of the earliest relations reported was that of a balance between minerals, especially calcium and phosphorus.

Many of the interrelations involve vitamins Vitamin E has been reported as sparing vitamins A and D. A sparing action has been noted between vitamin B_{12} and pantothenic acid. The vitamin B_{12} requirement is also influenced by the protein level and the amounts of methionine and choline present in the ration. The vitamin D required is related to the amounts of calcium and phosphorus supplied. Choline, biotin, and folic acid are involved in perosis and manganese metabolism. Thiamin has a relationship with the carbohydrate requirement. Niacin can spare the amino acid tryptophan. Ascorbic acid to a certain extent corrects the harmful effect of excess tyrosine.

The presence of labile methyl groups are necessary for nutrition. A certain amount of shifting can take place for this purpose between choline, methionine, and betaine.

A certain amount of substitution can take place between the amino acids. Cystine can in this way replace part of the methionine.

There is also some interrelationship between the vitamins, enzymes, and hormones. The function of these depend upon a proper balance in the body.

There exists a relationship between the requirement of the chick in early life and the amount of carry-over of nutrients from the egg. Hence, the diet of the dam influences the reaction of the chick. This might be considered a delayed nutritional effect.

The interrelations between nutrients are particularly important in the case of borderline or partial deficiencies.

Some nutritive factors will alter the microflora of the intestinal tract which will have an effect on the synthesis of nutrients which might have a direct effect upon the response of the bird to certain types of rations.

The feeding of animals is sometimes complicated by the presence in the ration of antimetabolites. The avidin of raw egg albumen will tie up the biotin and hence cause biotin deficiency. Heat treatment to inactivate the avidin will result in a normal response without any other change in the ration. The deficiency might also be overcome by the addition of more biotin. Similarly an antithiamin factor in raw fish has been the cause of thiamin deficiency in fur-bearing animals. Antimetabolites have also been reported for some of the other vitamins.

ENERGY

All energy comes from the sun. Energy might be defined as the ability or power to do work. In feeding stuffs, it is present as chemical or stored energy, expressed in this way by Liberty Hyde Bailey: "The blazing log gives back the glow of summer suns of long ago." In the formation of plant tissues, energy from the sun is stored in them. When the feed is consumed by the animal, it is broken down and the energy released. Carbohydrates and proteins are approximately equivalent in their energy values, producing 4 calories per gram. On the other hand, fats produce more energy per unit volume, the value of fats being 9 calories per gram.

A deficiency of energy[53] results in lower growth, poorer feathering, and reduced efficiency of feed utilization in chicks as well as poorer weight maintenance and lower egg production in hens. Increasing the energy content of some rations has resulted in improvement because energy rather than any of the other nutrients was the limiting factor. This largely explains the favorable results of the "high energy" rations.

The young chick compensates for a reduced dietary energy level by increasing feed consumption. Energy levels seem to be the major factor in controlling feed intake. Reduction of the dietary energy level is reflected in changes in the fat content of the carcass. Although large amounts of indigestible fibrous materials can be incorporated in a diet without affecting weight gains of young birds, body composition is greatly changed. Hence weight gains are not a satisfactory criterion in determining energy requirements for growth. Higher energy rations are necessary for higher fat content of the carcass, which influences the degree of pigmentation and appearance of the skin which are major factors in determining market quality.

Available energy values of feedstuffs as reported by Fraps[54] are given in Table 3. In general as the fiber of the feed increases, the energy value is lowered.

Sunshine or light has many effects upon the animal body. The antirachitic value of the ultraviolet rays has already been referred to in connection with vitamin D. The far-ultraviolet rays also are reported to have an antiseptic value. It has also been reported that bactericidal ultraviolet radiation[55] exerted a stimulatory effect upon egg production. The infrared rays have certain heat effects upon the body. The red rays of the visible spectrum are effective in the use of artificial illumination by stimulation of the pituitary gland, which in turn stimulates the reproductive system.

VARIATION IN COMPOSITION OF PLANTS

In dealing with feedstuffs, we must keep in mind the fact that they are mixtures of nutrients. In fact, most feeds contain all or most of the nutrients in varying proportions. No two feeds are alike in their composition. Variations will be found in the water content, ash, crude proteins, fiber, carbohydrates, and fats as well as in the various mineral constituents, vitamins, and amino acids. The problem in compounding a ration is to make a combination of ingredients in such a manner that these

various nutrients and constituents are furnished in quantities to meet the requirements for them. It not only is important to furnish a sufficient amount of each of the constituents but, in the case of those which might be harmful or which are very expensive, too great an excess must also be avoided.

RELATIONS BETWEEN PLANT AND ANIMAL TISSUES

CHEMISTRY OF ANIMAL LIFE. The relative proportion of the nutrients as found in animal tissues is shown in Table 1. Water comprises the largest single nutrient of both the fowl and the egg. Protein is also an important nutrient. Fat appears in fairly large quantities in the egg and in certain kinds of fowl. In the animal body, there is an inverse relation between fat and moisture. For example, analysis indicates a larger proportion of fat in the Plymouth Rock capon than in the Leghorn hen. This increase in fat is almost entirely at the expense of the water content. Carbohydrates are present in the body only in small amounts. They occur in the glucose of the blood and the glycogen of the liver and muscles.

The dry matter of the body is made up largely of carbon, oxygen, hydrogen, and nitrogen. Of the mineral elements, phosphorus and calcium are present in largest amounts, and sulfur, potassium, chlorine, sodium, magnesium, and iron in much smaller quantities.

COMPARISON OF PLANT AND ANIMAL TISSUES. There are a number of important differences in the composition of plants and animals. Poultry rations are made up largely of cereals and cereal by-products. A comparison, therefore of corn and the body of the hen will show these differences (Table 1).

One difference between these two is that corn is relatively low in water, whereas the animal body is made up of a large percentage of water. The body of the fowl contains more mineral matter,

TABLE 1. COMPOSITION OF PLANT AND ANIMAL TISSUES

	Corn, %	Leghorn Hen, %	Plymouth Rock Capon, %	Egg, %
Water	11.3	55.8	41.6	73.7
Protein	9.3	21.6	19.4	13.4
Fat	3.8	17.0	33.9	10.5
Carbohydrates	75.3	traces	traces	....
Mineral matter	1.3	3.8	3.7	1.0

proteins, and fat. On the other hand, the corn is composed largely of the carbohydrates.

Similarly, we find differences in the make-up of the amino acids. The animal proteins usually contain larger amounts of such amino acids as lysine, arginine, tryptophan, and histidine than the grains. There are also differences in the mineral constituents, the greatest difference occurring in the calcium content, which is high in the body of the hen and low in the grain.

CYCLE OF LIFE. A study of the composition of the animal body shows the end or aim of feeding. The presence of different elements and compounds in the body indicate that they must be supplied from some source. That source is the feed which the animal eats. Most of this food comes from plant substances.

The transformation and use of the food nutrients or the relation of food nutrients and the animal products derived therefrom are shown in Table 2.

In general, the nutrients found in the body of the fowl or the egg must appear in the ration. A common saying is that we must "feed a part to make a part." In the main, one nutrient cannot be substituted for another. There are, however, a few exceptions to this general statement. For example, carbohydrates can be used in part for fats, and fat can be substituted in part for the carbohydrates. Similarly, proteins can function the same as

TABLE 2. THE TRANSFORMATION AND USE OF THE FOOD NUTRIENTS OR THE RELATION OF FOOD NUTRIENTS AND THE ANIMAL PRODUCTS DERIVED THEREFROM

Kernel of Grain	Chemist's Report	Body of Fowl	Egg
Water	Moisture	Body fluids (water)	Water
Minerals	Ash	Bones (Ca, P) Body tissues (K, S, P) Blood (Fe)	Shell (Ca) Egg contents (P, S, K)
Proteins (gluten)	Crude protein or N × 6.25	Muscles Blood Nerves Feathers	Albumen Yolk proteins
Carbohydrates: Starches, sugars	Nitrogen-free extract	Glycogen Fat (energy)	Yolk fat
Cellulose	Crude fiber		
Lipids	Ether extract	Fat (energy)	Yolk fat
Vitamins		Vital organs Enzymes	Vitamins

carbohydrates and fats in furnishing energy. However, the reverse is not true, because carbohydrates and fats cannot function in place of the proteins.

FEED ANALYSES

The ordinary report of the chemist on feed analyses usually gives water or moisture, crude protein, fat or ether extract, crude fiber, mineral matter or ash, and nitrogen-free extract. All these are determined directly with the exception of the nitrogen-free extract, which is determined by difference. That is, the other nutrients for which direct analyses are made are added together and subtracted from 100. The nitrogen-free extract represents the difference between their sum and 100 per cent.

It is possible also to make other determinations in the laboratory, but they are usually not part of the routine analyses of feeds. Some of the vitamins can be measured chemically or microbiologically in the laboratory in a comparatively short time. Analyses can also be made for most of the mineral elements. It is also possible to make an energy determination of the feed.

In most states, a guaranteed analysis of feeding stuffs is required by law. This analysis must accompany the feed, and usually must include a guarantee of the minimum amount of protein and fat and the maximum amount of fiber. In animal protein feeds, the maximum amount of phosphorus or P_2O_5, which represents the amount of bone present, must also be given. For example, a meat scrap guaranteed to contain 50 per cent protein, 6 per cent fat, 3 per cent fiber, and 8 per cent phosphorus must contain at least 50 per cent protein, at least 6 per cent fat, and not more than 3 per cent fiber, or 8 per cent phosphorus.

COMPOSITION OF FEEDS

When formulating poultry rations, it is necessary to have information on the composition of feeds. In tables 3 and 4 the average composition of feeds commonly used in poultry ratios is given. Table 5 shows the vitamin content of ingredients commonly used in poultry feeding. Table 6 gives the approximate amino acid composition of certain feedstuff proteins.

TABLE 4. MINERAL MATTER CONTENT OF FEEDS USED IN POULTRY RATIONS

Feeding Stuff	Mineral Matter, %	Calcium, %	Phosphorus, %	Manganese, mg. per lb.
Alfalfa leaf meal, good	12.0	1.69	0.25	27.6
Alfalfa leaf meal, high in fiber	10.9	...	...	...
Alfalfa, green	2.3	0.35	0.07	5.6
Barley	2.8	0.06	0.37	8.0
Barley, Pacific Coast	2.6	...	...	...
Bone meal, steamed	81.3	29.30	15.10	5.1
Buckwheat	1.9	0.09	0.31	15.4
Buttermilk	0.8	0.14	0.08	...
Buttermilk, condensed	4.0	0.44	0.26	...
Buttermilk, dried	10.0	1.36	0.82	...
Corn, dent, Grade 2	1.2	0.02	0.27	2.5
Corn feed meal	2.0	0.03	0.34	...
Corn gluten feed	6.3	0.48	0.82	11.2
Corn gluten meal	2.5	0.13	0.38	3.4
Cottonseed meal, 43% protein	5.8	0.23	1.12	...
Dried distillers' solubles	7.4	0.30	1.41	29.6
Fish meal, all analyses	17.6	4.14	2.67	13.5
Fish meal, menhaden	18.0	5.30	3.38	10.2
Fish meal, sardine	14.9	4.21	2.54	10.3
Fish solubles, condensed	9.6	...	...	...
Hominy feed	2.9	0.22	0.71	6.9
Linseed meal, solvent process	5.6	0.39	0.87	18.4
Meat scraps, 55% protein	26 3	8.33	4.04	8.2
Meat and bone scraps, 50% protein	29.1	9.71	4.81	5.3
Milo grain	1.7	0.03	0.28	5.9

TABLE 4 (Concluded)

Feeding Stuff	Mineral Matter, %	Calcium, %	Phosphorus, %	Manganese, mg. per lb.
Molasses, cane	9.0	0.74	0.08	. . .
Oats	4.0	0.09	0.34	19.9
Oats, Pacific Coast	3.7	. . .	. . .	. . .
Oat kernels, without hulls	2.2	0.08	0.46	16.8
Pea seed, field	3 0	. . .	. . .	. . .
Peanut-oil meal, o.p. 13% protein	5.2	0.16	0.54	. . .
Rye	1 9	0.10	0.33	37.0
Skimmilk	0.7	0.13	0.10	0.1
Skimmilk, dried	7.8	1.30	1.03	0.8
Soybean oil meal, hydraulic or expeller	6.0	0.29	0.66	13.6
Soybean oil meal, solvent	5.8	0.30	0.66	13.8
Sunflower seed	3.1	. .	0.55	9.8
Tankage, 60% protein	20.2	6.37	3.23	10.0
Wheat	1 9	0.04	0.39	19.9
Wheat, soft Pacific Coast	1.9	. . .	. . .	. . .
Wheat bran	6.1	0.14	1.29	51.5
Wheat flour middlings	3 1	0.09	0.71	. . .
Wheat standard middlings	4.4	0.09	0.93	49.4
Wheat red dog	2.7	0.07	0.51	16.3
Whey, dried	9.9	0.86	0.72	2.0
Yeast, dried brewers'	7.9	0.13	1.56	2.5
Limestone	. .	38.30	. . .	. . .
Oyster shell	.	37.90	. . .	. . .

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TABLE 3. AVERAGE COMPOSITION OF ORGANIC NUTRIENTS AND AVAILABLE ENERGY OF FEEDS USED IN POULTRY RATIONS

Feeding Stuff	Protein, %	Fat, %	Fiber, %	N-Free Extract, %	Digestible Protein, %	Total Digestible Nutrients	Energy, cal /lb.
Alfalfa leaf meal, good	21.2	2.8	16.6	39.7	16.1	56.7	314
Alfalfa leaf meal, high in fiber	19.6	2.7	20.7	38.9	14.3	53.2	. . .
Alfalfa, green	4.5	0.9	7.2	10.4	3.4	14.7	. . .
Barley	12.7	1.9	5.4	66.6	10.0	77.7	811
Barley, Pacific Coast	8.7	1.9	5.7	70.9	6.9	78.7	. . .
Bone meal, steamed	7.1	3.3	0.8	3.8	. . .	. . .	202
Buckwheat	10.3	2.3	10.7	62.8	7.4	62.2	700
Buttermilk	3.5	0.6	. . .	4.5	3.3	9.1	. . .
Buttermilk, condensed	10.9	2.2	. . .	12.6	9.8	26.5	241
Buttermilk, dried	32.4	6.1	0.3	43.3	29.2	81.0	707
Corn, dent, Grade 2	8.6	3.9	2.0	69.3	6.6	80.1	1145
Corn feed meal	9.8	4.7	2.9	69.2	7.5	83.1	1145
Corn gluten feed	25.5	2.7	7.8	48.8	21.9	76.0	565
Corn gluten meal	43.1	2.0	4.0	39.8	36.6	80.2	839
Cottonseed meal, 43% protein	42.7	6.1	10.6	27.0	34.2	72.6	694
Dried distillers' solubles	28.7	7.9	2.6	48.4	19.5	77.1	853
Fish meal, all analyses	63.9	6.8	0.6	4.0	56.2	72.8	898
Fish meal, menhaden	62.2	8.5	0.7	4.2	50.4	71.6	. . .
Fish meal, sardine	67.2	5.0	0.6	5.4	55.1	68.9	823
Fish solubles, condensed	29.3	8.4	. . .	2.2	26.1	42.3	. . .
Hominy feed	11.2	6.9	5.2	64.2	8.0	84.5	860
Linseed meal, solvent process	36.9	2.9	8.7	36.3	31.0	72.3	586
Meat scraps, 55% protein	55.0	10.9	1.2	0.5	47.3	67.9	724
Meat and bone scraps, 50% protein	51.0	10.1	2.1	1.6	41.8	64.6	724
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80.1	1144

TABLE 3 (Concluded)

Feeding Stuff	Protein, %	Fat, %	Fiber, %	N-Free Extract, %	Digestible Protein, %	Total Digestible Nutrients	Energy, cal./lb.
Molasses, cane	2.9	...	...	62.1	...	54.0	714
Oats	12.0	4.6	11.0	58.6	9.4	70.1	817
Oats, Pacific Coast	9.0	5.4	11.0	62.1	7.0	72.2	...
Oat kernels, without hulls	16.3	6.1	2.1	63.7	14.7	92.0	1155
Pea seed, field	23.4	1.2	6.1	57.0	20.1	77.9	888
Peanut-oil meal, o.p. 43% protein	43.1	7.6	13.9	23.0	39.2	82.0	731
Rye	12.6	1.7	2.4	70.9	10.0	76.1	817
Skimmilk	3.6	0.1	...	5.1	3.4	8.7	...
Skimmilk, dried	31.7	1.2	0.2	50.3	31.2	80.7	525
Soybean oil meal, hydraulic or expeller	44.3	5.3	5 7	29.6	37.2	78.4	674
Soybean oil meal, solvent	46.1	1.0	5.9	31.8	42.4	78.5	565
Sunflower seed	16 8	25.9	29.0	18.8	13.9	76.3	950
Tankage, 60% protein	60.6	8.5	2 0	1.8	51.5	68.4	676
Wheat	13.2	1.9	2.6	69.9	11.1	80.0	1024
Wheat, soft Pacific Coast	9.9	2.0	2.7	72.6	8.3	79.9	...
Wheat bran	16.9	4.6	9.6	52.9	13.7	67.2	478
Wheat flour middlings	18.3	4.2	3.8	59.8	16.1	78.9	720
Wheat standard middlings	18.1	4.8	6.5	55.8	15.0	77.2	581
Wheat red dog	18.2	3.6	2.6	61.9	16.0	85.6	1020
Whey, dried	12.2	0.8	0.2	70.4	11.0	78.3	490
Yeast, dried brewers'	49.3	1.0	3.7	31.9	42.4	70.5	476

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TABLE 5. VITAMIN CONTENT OF INGREDIENTS COMMONLY USED IN POULTRY FEEDING

Feedstuff	Vitamin A Activity, I.U. per lb.	Riboflavin, mg. per lb.	Pantothenic Acid, mg. per lb.	Niacin, mg. per lb.	Thiamin, mg. per lb.	Biotin, mg. per lb.	Choline, mg. per lb.	Folic Acid, mg. per lb.	Pyridoxine, mg. per lb
Alfalfa leaf meal, dehydrated	113,667	8.7	15.3	18.0	2.5	0.15	?	?	?
Alfalfa leaf meal, sun cured	50,000	7.2	12.6	21.1	2.0	...	...	...	...
Alfalfa meal, dehydrated	72,333	6.7	17.4	?	2.0	?	462	3.93	?
Alfalfa meal, sun cured	27,667	5.4	12.0	17.7	1.1	...	...	...	...
Barley	317	0.8	3.0	27.2	2.6	0.06	450	0.27	1.62
Brewers' yeast, dried	0	18.6	51.0	228.1	35.0	?	1,635	?	?
Buckwheat	0	0.7	5.7	9.1	2.1	...	...	...	...
Buttermilk, dried	0	14.9	15.8	3.7	1.6	?	500	?	?
Corn, yellow	3,667	0.5	2.3	9.0	1.9	0.03	200	0.14	?
Corn, yellow, stored 2 yrs	1,833	?	?	?	?	...	...	...	...
Corn gluten meal	16,667	0.6	5.3	23.4	0	?	135	0.10	?
Cottonseed meal	150	2.2	5.0	14.5	3.3	?	320	1.01	?
Distillers' dried solubles	?	5.2	8.9	54.3	2.7	1.26	1,500	?	?
Fish meal, menhaden	?	2.2	?	25.9	0.2	...	...	...	...
Fish meal, sardine	?	2.5	3.2	11.4	0.4	?	1,500	?	?

TABLE 5 (Concluded)

Feedstuff	Vitamin A Activity, I.U per lb	Ribo-flavin, mg. per lb	Panto-thenic Acid, mg. per lb.	Niacin, mg. per lb.	Thiamin, mg per lb	Biotin, mg. per lb.	Choline, mg. per lb.	Folic Acid, mg. per lb.	Pyri-doxine, mg. per lb.
Fish solubles, condensed	?	9.8	18.9	166.5	2.0	0.06	1,800	?	5.68
Meat and bone scrap	0	2.1	1.5	21.4	?	?	900	?	?
Meat scrap (55%)	0	2.1	1.8	20.2	0.5	?	1,300	?	?
Oats	83	0.5	6.0	6.3	2.8	0.13	435	0.10	?
Peanut meal	133	1.1	24.1	77.5	3.3	?	840	?	?
Rice bran	0	1.0	10.3	129.1	10.3	. . .	. . .	. . .	. . .
Skimmilk, dried	0	9.5	13.6	6.2	1.6	?	612	0.27	?
Soybean oil meal, solvent	?	1.9	7.3	14.5	0.8	?	1,285	?	?
Wheat	0	0.5	6.3	24.1	2.3	0.04	458	0.20	?
Wheat flour middlings		0.8	4.5	14.2	6.0	?	450	?	?
Wheat standard middlings	0	0.8	9.3	41.3	5.8	?	547	0.41	?
Wheat bran	133	1.4	10.6	63.5	3.9	?	502	0.10	?
Whey, dried	0	13.0	22.4	5.1	1.8	?	1,635	?	?

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TABLE 6. AMINO ACID COMPOSITION OF POULTRY FEEDSTUFFS

	Percentage of Feedstuffs						
	Crude Protein	Arginine	Lysine	Methionine	Cystine	Tryptophan	Glycine
Alfalfa meal	20	1.0	1.0	0.36	0.38	0.35	?
Alfalfa meal	18	0.9	0 9	0.32	0.34	0.32	?
Barley	12	0.5	0.3	0.13	0.20	0.13	?
Barley	9	0.4	0.2	0 10	0.15	0.10	?
Blood meal	84	3.0	7.2	1.00	1 50	1.18	trace
Buttermilk, dried	32	1.0	2.2	0.67	?	0.41	0 2
Corn	9	0.4	0 2	0.21	0.15	0.07	0.4*
Corn gluten meal	42	1.3	0.7	0.97	0.68	0.33	2.1*
Cottonseed meal	43	3 5	1 6	0.71	0.97	0.46	2.3
Distillers' solubles, dried	26	0.8	0 8	0.41	0.26	0.12	?
Fishmeal	70	5.0	6.4	2.20	1.18	0.98	4.7
Fishmeal	65	4.6	5.9	2.00	1.10	0.91	4.4
Fishmeal	60	4.0	5.4	1.80	1.00	0.84	4.0
Fish solubles, condensed	35	1.5	1.7	0.60	0.21	0.12	2.3
Linseed meal	35	2 7	1.1	0.84	0.66	0.56	1.8*
Meat scrap	55	3 9	3.4	1.10	0.77	0.44	2.2*
Meat scrap	50	3.0	2.7	0.70	0.60	0.35	2.0*
Milo	11	0 4	0.3	0.16	0.20	0.09	?
Oats	12	0.7	0 4	0.23	0.19	0.14	?
Oats	9	0 5	0 3	0.17	0.14	0.10	?

TABLE 6 (Concluded)

	Percentage of Feedstuffs						
	Crude Protein	Arginine	Lysine	Methionine	Cystine	Tryptophan	Glycine
Peanut meal	44	4.4	1.3	0.49	0.70	0.44	2.5
Peas, dry	24	1.7	1.4	0.19	0.34	0.19	?
Rye	12	0.5	0.4	0.16	?	0.16	?
Skimmilk, dried	35	1.1	2.5	0.81	0.42	0.45	0.2
Soybean meal	45	2.8	2.7	0.62	0.66	0.53	7.6
Sunflowerseed meal	45	3.7	1.9	1.53	0.72	0.59	2.2*
Wheat	13	0.5	0.3	0.21	0.24	0.14	
Wheat	10	0.4	0.3	0.16	0.19	0.11	?
Wheat bran	15	0.9	0.5	0.17	0.19	0.21	?
Wheat middlings	16	0.9	0.4	0.14	0.19	0.14	?
Whey, dried	12	0.4	1.0	0.32	0.41	0.18	0.0
Yeast, dried brewers'	45	2.0	3.1	0.84	0.54	0.55	?

*Minimum value based on feeding tests.

Taken from Table 6 "Recommended Nutrient Allowances for Domestic Animals," Number 1. Recommended Nutrient Allowances for Poultry, A report of the Committee on Animal Nutrition of the National Research Council, Washington, D. C., revised March, 1950.

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CHAPTER 4

MEASURING THE VALUE OF FEEDS

In order to be of use to the animal, the feed which is eaten must be digested, absorbed into the body proper, and then made use of by the body.

DIGESTION

PHYSIOLOGY OF THE DIGESTIVE TRACT OR ALIMENTARY CANAL

The alimentary canal is a long tube passing from the mouth to the vent, with certain enlargements for the storage of food and waste. The digestive tract of the fowl is composed of the following parts (Fig. 15).

MOUTH. The mouth is the first part of the digestive tract. It is the place where the food enters. A distinctive character of the mouth of the bird is the absence of lips and teeth.

ESOPHAGUS OR GULLET AND CROP. Upon leaving the mouth, the feed is forced into the gullet by the tongue. The gullet itself serves only as a passage for the food. However, immediately before entering the body cavity, the esophagus enlarges to form a pouch, called the crop. The crop functions as a storage place for feed. Hard material, like grain, might remain in the crop for 12 hours or more. While in the crop the food becomes softened.

PROVENTRICULUS. The proventriculus is the secretory part of the hen's stomach. It is called the glandular stomach because its thickened walls contain the gastric glands, which secrete the gastric juice. The feed is not kept in the proventriculus for any length of time, but the gastric juice is secreted and mixed with the feed as it passes through it

GIZZARD. The second part of the hen's stomach is the gizzard. The gizzard is oval, with two openings on its upper side, one connecting with the proventriculus and the other with the small intestine. The gizzard is made up of two thick, red, powerful muscles covered internally with a thick horny epithelium.

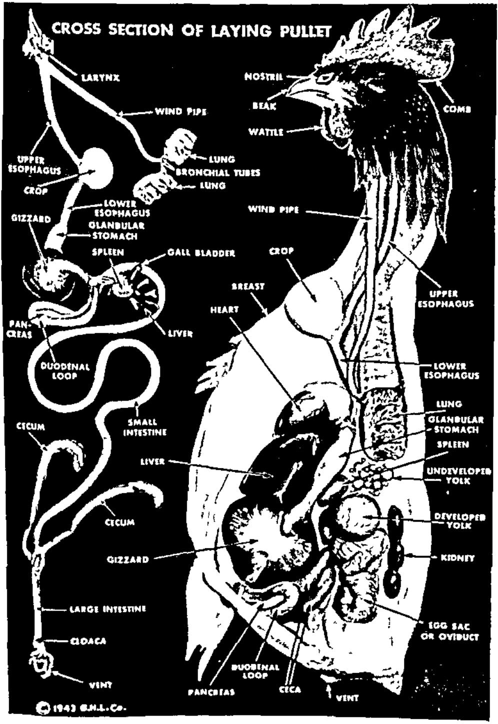

Fig. 15. Cross section of a laying pullet showing the digestive tract.

The function of the gizzard is to grind the food. The grinding action is aided by the presence of grit in the gizzard.

SMALL INTESTINE. From the gizzard, the feed, which has been thoroughly ground and partially digested, passes into the small intestine. The upper portion of the small intestine, which forms a U-shaped loop, is known as the duodenum. Most of the gastric digestion takes place in the duodenum. Further digestion of the feed and absorption of the nutrients take place in the lower intestines.

CECA. At the juncture of the small and large intestines are two blind pouches, called the ceca. They are usually 4 to 6 inches long and are more or less completely filled with fecal matter. It is believed that some bacterial digestion of fiber occurs in the ceca. Some absorption also takes place here.

LARGE INTESTINE OR RECTUM. The large intestine in fowls is relatively short. Its chief function seems to be to absorb moisture from the intestinal content.

CLOACA. The alimentary canal is terminated by the cloaca, a chamber common to the digestive and the genito-urinary systems. The cloaca opens externally at the anus.

ORGANS ASSOCIATED WITH THE ALIMENTARY CANAL. The liver is a bilobed organ, brown in color, which elaborates the bile. The bile functions in the digestion of fat. Bile is stored in the gall bladder and is emptied through the bile ducts into the distal lobe of the duodenum.

The pancreas is a long flesh-colored organ lying in the loop of the duodenum. It secretes the pancreatic juice, which contains ferments that act upon the proteins, carbohydrates, and fats.

THE DIGESTIVE PROCESS

Digestion includes all those physical and chemical processes by means of which the ingested food is broken down and rendered soluble, ready for absorption into the body proper It includes such physical processes as swallowing, peristalsis, and the grinding action of the gizzard, as well as such chemical processes as the solvent action of water, the action of various ferments or enzymes, and the action of bacteria.

Digestion of feed is usually not complete. The part of the feed that has not been digested is excreted in the feces.

THE DIGESTIVE JUICES

The action of the ferments or enzymes constitute the most important part of digestion. The digestive juices are fluids, excreted from the walls of the digestive tract or associated organs and containing water, enzymes, and other products necessary for rendering the foods soluble.

THE SALIVA. Saliva is not an important digestive juice for the hen because it is secreted in very small quantities. It contains ptyalin, which converts some of the starch to maltose. The saliva also helps to moisten the food.

THE GASTRIC JUICE. The gastric juice is composed of water, hydrochloric acid, and enzymes, such as pepsin and rennin. It is acid in reaction and functions mainly in breaking down proteins.

THE INTESTINAL JUICES. The intestinal juices are composed of water, bile, pancreatic juice, and the intestinal juice. The bile emulsifies and helps digest the fat. The pancreatic juice contains the enzyme trypsin, acting upon proteins, amylopsin, acting upon starch, and steapsin, acting upon fat. The intestinal juice contains erepsin, which breaks down proteins, and invertases, which act upon the sugars.

THE DIGESTION OF FOOD COMPOUNDS

CARBOHYDRATES. The carbohydrates must be converted to single sugars before they can be absorbed by the animal body. The ptyalin of the saliva and the amylopsin of the pancreatic juice act upon starch, changing it to dextrin and then to maltose. The invertases of the intestinal juice act upon the maltose and similar sugars, changing them to the single or glucose-like sugars.

Fiber is digested only to a small extent in poultry. The breakdown of fiber is thought to be accomplished by means of bacterial fermentation, which takes place chiefly in the ceca.

PROTEINS. Proteins must be converted to amino acids before they can be absorbed by the animal body. In this process a number of cleavage products are produced. Primary protein derivatives, which are insoluble, are mostly metaproteins and coagulated proteins. The secondary protein derivatives are soluble and are composed chiefly of proteoses, peptones, and peptides.

The enzymes of the gastric juice act upon the proteins, changing them to metaproteins, proteoses, peptones, and peptides.

The trypsin of the pancreatic juice acts in the same way as the gastric juice, except that peptones and peptides are further partially hydrolyzed to amino acids. The digestion of the protein is completed by the erepsin of the intestinal juice, which converts the proteoses, peptones, and peptides to amino acids.

FATS. The fats must be converted to fatty acids and glycerol in order to be absorbed by the body. The bile, which contains alkaline salt, saponifies, emulsifies, and dissolves the fats and fatty acids. The steapsin of the pancreatic juice can then convert the fat to fatty acids and glycerol.

SUMMARY OF THE DIGESTION OF ORGANIC NUTRIENTS. The digestion of feed as it passes through the digestive tract is summarized in Table 7.

TABLE 7. DIGESTION OF THE ORGANIC NUTRIENTS

Region	Secretion	Enzyme	Substance Affected	Products Formed
Mouth	Saliva	Ptyalin	Starch	Maltose*
Proventriculus	Gastric juice and HCl	Pepsin	Protein	Intermediate* N products
Small intestine	Pancreatic juice	Amylopsin	Starch	Maltose*
		Steapsin	Fat	Fatty acids and glycerol†
		Trypsin	Protein and intermediate N products	Amino acids†
	Intestinal juice	*Erepsin*	*Intermediate* N products	*Amino acids*†
		Invertases	Sugars*	Single sugars†

* Intermediate products.
† Final or absorption products.

COMPARISON OF DIGESTION IN DIFFERENT ANIMALS

DIFFERENCES IN STRUCTURE. The viscera in poultry are less complex than in mammals. This is especially true of the genito-urinary organs. In poultry, the urine is not stored in a bladder, but is poured into the cloaca, where it comes in contact with the feces. The urine is excreted in the form of uric acid, which appears as whitish crystals In mammals, the urine is excreted as soluble urea.

An outstanding feature of the fowl is the relative shortness of the large intestine. The ratio of the large to the small intestines

is about 1 to 30. For the farger farm animals this ratio is about 1 to 3 or 4.

The general structure of the digestive tract of the fowl suggests rapid digestion. The shortness of the tract is a carnivorous *characteristic, whereas the nature of the diet and the thorough* grinding of feed in the gizzard are herbivorous characteristics.

The stomach of the hen is composed of two parts as compared with a single stomach for the horse and the pig, and a stomach with four divisions for the ruminant.

Fowls secrete very little saliva and the concentration of ptyalin is very low. In ruminants, the amount of saliva secreted is large and the concentration of ptyalin is not great. In swine, saliva secretion is fairly large and the concentration of ptyalin is also appreciable.

DIFFERENCES IN DIGESTION OF NUTRIENTS. The digestibility of the different nutrients varies with the different farm animals.[1] This is illustrated in Table 8.

TABLE 8. ORDER OF EFFICIENCY OF DIGESTION OF THE NUTRIENTS BY VARIOUS ANIMALS

	Protein	Ether Extract	Nitrogen-Free Extract	Crude Fiber
Ruminant	5	4	4	1
Horses	3	5	3	2
Rabbits	4	3	2	4
Swine	1	2	1	3
Hens	2	1	5	5

The nutrient which is digested to the greatest extent by poultry is the nitrogen-free extract. Next in order of digestibility are *fat*, *protein*, and *fiber*.

Fiber is digested to a considerable extent by the other farm animals. In ruminants, this takes place in the rumen, in the horse and swine, in the large intestine. Poultry digests fiber only to a very limited extent, and digestion is thought to occur in the ceca. The amount of fiber digested varies with different feeds. Many show no digestion of fiber at all, and in any feed it rarely goes over 15 per cent. A larger percentage of the fiber of thin-husked varieties of oats is digested than of oats with thick hulls.

The digestion of fats also varies with different feeds. The fat of corn seems to be much more digestible than the fat of oats or barley or wheat.

Organic matter low in fiber is digested to nearly the same extent in all animals.[1] However, with an increase in crude fiber the digestion coefficient of the organic matter decreases rectiliniarly for all animals. The unit decrease, however, is greatest for hens and swine and least for ruminants, so that with a feed containing 35 per cent of fiber, ruminants would digest about 60 per cent of the organic matter, whereas hens would digest 20-25 per cent. With feeds containing very little fiber the different species of animals would all digest approximately 90 per cent of the organic matter. For the best digestibility of organic matter, the feed for hens should not exceed 5 per cent of fiber.

The digestibility of feed does not seem to be affected to any extent by grinding. Cooking increases the digestibility of some of the nutrients, particularly starch. The digestibility of proteins decreases with feeds of low protein content.

TIME REQUIRED FOR FOOD TO PASS THROUGH THE INTESTINAL TRACT. The time required for food to pass through the intestinal tract depends upon the type of feed and the condition of the bird. The North Carolina and California experiment stations[2] report that it took approximately 4 hours for feed to pass through the intestinal tract of laying hens and growing fowl. For nonlaying hens, this time was extended to 8 hours,and, for broody hens, to approximately 12 hours.

The first appearance of any soft foods in the feces has been reported to be 2 to 3 hours after ingestion; for the appearance of grains, this time is extended to 2½ to 3½ hours.

As already indicated, feed is stored in the crop of the bird. The time required for the feed to leave the crop will depend upon the type and condition of the feed. The disappearance of grains from the crops of hens is similar for the various types of grain, except that oats are retained in the crop longer than corn and wheat. Whole corn remains in the crop longer than cracked corn, which in turn is retained longer than corn meal. Boiled oats are not retained in the crop as long as dry oats. Wet mash passes from the crop more rapidly than a dry mixed mash. Experiments at Cornell[3] indicated that approximately the following percentages of a given grain intake were present in the crop:

	Per Cent
After 4 hours	70-80
After 8 hours	55-65
After 12 hours	35-45
After 16 hours	25-35
After 20 hours	10-20
After 24 hours	0-10

Results from Germany[4] indicated that it took 50 to 70 hours entirely to clear the digestive tract of corn, 102 hours for wheat, and 120 hours for barley and oats.

ASSIMILATION

Absorption of the food material takes place largely in the small intestine. Some absorption occurs in the large intestine and in the ceca. In order to be absorbed, the feed must be in a liquid form.

The food nutrients are absorbed through the epithelium of the digestive tract by a process similar to osmosis. The glucose-like sugars, the amino acids, and the mineral matter enter directly into the blood system. The fatty acids and glycerol enter the lymphatic system, which later combines with the blood system.

METABOLISM

Metabolism consists of all those chemical changes which food nutrients undergo from the time they are absorbed into the body proper until they appear as excretory products. Metabolism includes the distribution of the absorbed food, the building of body tissues, the breaking down of body tissues, and the absorption or release of energy. The building of body tissues is a synthetic process called anabolism. The breaking down of body tissues is an oxidative process called catabolism.

DISTRIBUTION OF FOOD NUTRIENTS. The end products of fat digestion, namely, soaps, organic acids, and glycerol, are taken into the epithelial cells, which reconvert them into fat. The fat then passes through the lacteals into the lymphatic vessels, then into the veins and arteries to the capillaries, the lymph spaces, and then to the body cells.

The glucose-like sugars, after passing through the epithelium, are taken up by the capillaries, transported to the veins, and to the liver, where they might be converted into glycogen. The glycogen is reconverted to glucose, which is carried by the veins to the arteries, then to the capillaries, the lymph spaces, and to the cells, where it is utilized or where it might be converted and stored as glycogen.

The amino acids and mineral matter are taken up by the capillaries, transported to the veins, then to the liver, then through the veins and arteries to the capillaries, the lymph spaces, and to the cells, where they are used.

ANABOLISM. The building up processes, involving glucose, consist of its conversion to glycogen or to fats or, with the addition of ammonia, to amino acids. The amino acids are converted to proteins, or, if deaminized, to glucose or fats. The fatty acids and glycerol are converted either to fat or to glucose.

CATABOLISM. The breaking-down process of glycogen involves its conversion to glucose and then to carbon dioxide and water, with the release of energy. Fat is broken down to fatty acids and glycerol, which in turn are converted to glucose and then to carbon dioxide and water, with the release of energy. Proteins are broken down into amino acids, and these into ammonia and glucose. The ammonia is converted into uric acid, which is then excreted. The glucose is broken down to carbon dioxide and water, with the release of energy.

EXCRETION OF BODY WASTES. Carbon dioxide and water, in the form of vapor, are excreted from the lungs. Water, ammonia, and, in come cases, minerals are lost through the urine. The remainder of the body wastes is excreted in the feces. This remainder comprises the minerals and some nitrogenous matter.

SOME CONDITIONS AFFECTING METABOLISM. Growth constitutes a storage chiefly of protein tissue and mineral tissue in the body. In fattening, fatty tissue is stored as energy. A hen in production builds up eggs from the simple products derived from the feed. Sometimes stored tissue is used for this purpose. In that case, the bird loses weight. The bird, if starving, will first use the available glycogen for energy, then the body fat, and finally, if necessary, the protein tissues.

THE NITROGENOUS METABOLISM OF BIRDS COMPARED WITH MAMMALS. In mammals, the urine is excreted and can be collected separately. In birds, the uric acid is excreted with the feces.

Uric acid, a highly insoluble compound, is the end product of nitrogenous metabolism in birds. It is believed that the synthesis of the uric acid takes place in the liver. The uric acid has a relatively small amount of water, which evaporates quickly.

In mammals, the urea is a highly soluble compound. The mammalian urine contains a large amount of water and is rich in such salts as chlorides, sulphates, and phosphates of lime and magnesium. The uric acid of birds contains little or none of the minerals, which in their case are excreted into the intestines

minations of poultry feeds, when dried liver was given a value of 100. dried skimmilk rated 20 and alfalfa meal 10. This meant that dried skimmilk contained 1/5 the amount of riboflavin which the dried liver had, and alfalfa meal contained 1/10 that of dried liver or 1/2 the amount found in dried skimmilk.

CARBON BALANCE. This measure requires the use of a respiration apparatus. In it are measured the nitrogen and carbon intake of the feed and the nitrogen and carbon outgo, as represented in the feces, urine, carbon dioxide, methane, and the like. From the difference, which represents the gains by the animal, the amount of protein and fat stored in the body can be calculated.

ENERGY BALANCE. In getting the energy balance of a feed a respiration calorimeter must be used. The intake of calories in the feed is compared with the outgo of calories as represented in the feces, urine, methane, and other waste products. The difference represents the calories stored by the animal.

MINERAL BALANCE. A comparison can be made of the amount of any of the mineral elements ingested, as compared with the amount of the minerals excreted. If the intake is greater than the outgo, some of the mineral is being stored in the body and the animal is said to be in a positive mineral balance. If the reverse is true, the animal is said to be in a negative mineral balance.

FAT BALANCE. Similarly, a feed or combination of feeds may keep the bird in a positive or negative fat balance. In this case the carbohydrates of the feed must also be taken into consideration.

DETERMINING REQUIREMENTS FOR FOOD

The object of determining the requirements for food is to establish standards by which we can feed our animals for specific purposes. Determining the requirements for food, or for the various nutrients, must be done by means of biological analyses, that is, by actual feeding trials. A number of different methods have been used for doing this.

OBSERVATION AND EXPERIENCE. This might be called a trial and error method. Frequently it is an extremely costly method because there are likely to be many mistakes and failures and often misinterpretation By observation, it is possible to know whether or not we are getting maintenance of the individual, production, or reproduction which are satisfactory. This

method frequently causes waste of food by providing rations in which the food nutrients are present in wrong proportions. It does not get at fundamentals. In the long run results may frequently be fairly satisfactory. A conspicuous example of this is the knowledge which we have secured in the feeding of horses.

COMPARATIVE FEEDING TRIALS. Most of the early feeding experiments were of this nature. For example, in comparing the feeding value of corn, wheat, and oats for hens, we might have fed these grains ad libitum and noted the results in gain or loss and production. Or the value of proteins might have been compared by supplying proteins in different forms, such as meat scrap, fish meal, and dried milk. Many of the comparative feeding trials were not very accurate because there were too many variables and because the nutrients must be fed below the minimum amount necessary in order to get a measure of comparative values.

REFINED FEEDING EXPERIMENTS. These represent more nearly controlled feeding trials. In order to get an accurate measure, either purified diets or diets of known values are used. In qualitative feeding experiments, additions of known nutrients, singly and in various combinations, are then made to the basal ration. In this way the nutrient deficiencies of a feed or ration can be determined. In quantitative experiments, the ration must be complete in every known respect, except the nutrient under test. The nutrient then must be fed in amounts both below and above the requirement in order to measure the exact amount that is essential.

SOME ESSENTIAL PROVISIONS FOR CONDUCTING AND *INTERPRETING EXPERIMENTS IN POULTRY NUTRITION*

In planning experiments in poultry nutrition, the aim should be to establish fundamental principles. In conducting experiments to do this, some essential provisions must be met. These same provisions can be kept in mind as a guide in passing judgment on the value of experimental work.

PROPER EXPERIMENTAL SETUP. An experiment should eliminate all variables, except the one under study. All other known requirements should be adequately met. The stock used should be obtained from the same breed, strain, and source. Parent stock should be fed and managed uniformly. The birds in an experiment should be distributed evenly in respect to such factors as size, age, sexual maturity, inheritance, previous egg

production, condition, and health. Chicks hatched in different incubators should also be distributed evenly.

The basal ration should consist of as few ingredients as possible. Only ingredients of known feeding value should be used. Whenever possible, enough of the basal ration should be prepared in advance to last for the entire experiment, except where there is the possibility of nutrient deterioration. The basal ration, when properly supplemented with the variable factors, should produce normal growth, production, or reproduction. A routine chemical analysis should be made of all basal rations and supplements. Analyses should be made also of any other nutritive factors, whenever these are involved in the experiment. In order to obtain proportionate consumption of every ingredient of the ration, it should be given in the form of a single finely ground mixture, except where the mechanical condition of the feed is the factor under study. It is desirable to give fresh feed in such quantities that the birds will consume nearly all of it before the next feeding. The time of feeding should be as regular as possible.

In conducting an investigation which involves several successive experiments it is essential that all conditions in each experiment be similar. This applies particularly to such environmental conditions as length of day, housing, temperature, and the like. The experimental period must be of sufficient length to make it possible to draw accurate conclusions from the results obtained. Experiments should be conducted as long as there is any possibility of obtaining significant differences.

PROPER RECORDS. It is always wise to weigh the feed weekly to obtain records of feed consumption, and it is necessary where conclusions are to be based upon food intake The cause of all mortality should be determined Trapnesting is desirable for all egg production studies.

All birds should be identified in some manner and weighed individually at frequent intervals. Individual or replicate records are necessary in order to apply biometrical methods of analysis to the growth results.

All pertinent physiological, histological, and physical studies and chemical analyses should be applied to the experiment

INTERPRETATION OF DATA Unless sexed chicks are used, all growth results with chicks should be weighted for sex influence. Sampling of birds for analyses should be representative in age, size, sex, and experimental conditions

Biometrical methods of analysis should be applied to all re-

sults, whenever possible, to determine if differences obtained are significant. Final conclusions should be based on as many methods of measurement as can be applied, in order to avoid wrong interpretation of results and to make them conclusive.

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CHAPTER 5

POULTRY FEEDS—CEREALS, SEEDS, AND OTHER MASH INGREDIENTS

The grain and mash mixtures constitute the bulk of the feed consumed by poultry. The mixtures must possess certain desirable characteristics, which in turn are influenced by the nature of the ingredients used. In order to encourage sufficient food consumption, the feeds must be palatable. It does not hold, however, that because a single feed is not entirely palatable, it must be avoided altogether. It may possess other qualities which render it especially valuable, in which case small amounts could be used, particularly when mixed with ingredients that are extremely palatable. It is the nature of the feed as a whole that is important.

The feed must be of a proper mechanical condition as regards size and hardness of particle, bulk, and consistency when mixed with water. The grains should not be too large or too hard. The ground feeds should not be too bulky or too concentrated. They should not be sticky when mixed with water, nor should they be too crumbly. The mash should be ground evenly and be uniform as to color, in order not to encourage picking over and possible wastage by the birds.

USE OF GROUND FEEDS IN POULTRY RATIONS

Sometimes the question is raised as to why a mash is used. Ground feeds are valuable for various reasons. One of the arguments advanced is that this feed saves the gizzard the work of grinding and in that way makes available a larger amount of the feed for useful purposes; or, stated in another way, saves some of the energy required in grinding. That is probably true when we consider the feeding of an entire whole-grain ration, as compared with an entire mash ration. If part of the feed is given as ground feed, as compared to the whole form, the hens will eat a larger amount of feed. This is important when we keep in mind that our results in growth and production depend upon feed consumption. Another reason is that it enables us to make use of

by-products that have excellent feeding value and that are comparatively cheap in cost. It provides a convenient way to feed animal protein by using meat, milk, or fish products as mash ingredients. Sometimes it is stated that the feeding of all mash makes it easy to balance the ration. This statement is true if we consider the effect on the nutritive ratio when we use different proportions of grain and mash.

USE OF GRAINS IN POULTRY RATIONS

In the United States corn is the leading grain fed to poultry. This is true of all parts of the country except in the Western States where wheat is more important. Oats are almost as popular as wheat and are most important in the North Central States. Barley is important only in the Western States. Sorghum grains are important only in about a half dozen states where they are grown.

In making up rations for poultry, it is advisable to use largely the grains that are low in fiber, such as corn and wheat. It has been shown by the South Dakota Station[1] that fiber grains alone, such as barley, oats, buckwheat, and emmer, gave poor production and unsatisfactory results, whereas corn and wheat added to the ration gave decidedly better results. Small variations in the rapidity of growth, production, and hatchability were noted when feeding low- and high-test weight corn, wheat, and barley. The amounts of the fiber grains used will depend somewhat upon the fiber content of the ration. In the scratch grain, palatability must also be considered. Probably not more than 1/3 of the scratch grain should consist of high-fiber grains.

The various grains differ in their value for poultry feeding. If used singly in large amounts, the results will be influenced by the nature of the grain. Experiments at the Iowa Agricultural Experimental Station[2] showed that rations consisting largely of ground oats are more satisfactory for chicks than rations containing large amounts of barley, wheat, or corn. The Indiana Station[3] reported little difference in rate of growth and feed efficiency of chicks which received rations containing about 40 per cent of corn, wheat, or half corn and oats.

Harshaw[4] has shown that the different cereals have varying effects upon the composition of the birds, as represented by the total edible portion and fat content of the edible portions. Corn showed a tendency to deposit more fat than oats, wheat, or barley. He suggests that a mixture of two or more cereals is desirable in feeding poultry for market.

The various grains differ also in their relative value. Experiments with laying hens, reported from Germany,[5] group the four cereals in the following order with regard to their general utility —wheat, oats, rye, barley.

From a review of published data, Crampton[6] indicates that the cereals may be rated in the following order. For growth: oat groats, barley, maize, wheat, rye; for laying and breeding: maize, barley, wheat, oats, rye; for fattening: maize, barley, wheat, oats. When the ration is scientifically balanced, the differences between barley, maize, and wheat are very small and likely to be masked in many cases by differences in the quality of different samples of grains.

Comparing digestible nutrients present in feed grains, Biely[7] gives the following ratings: corn, 100%; wheat, 95.5%; rye, 94.0%; barley, 87.5%; and oats, 84.3%.

It is possible to use a large proportion of a single grain. The Wyoming Station[8] reported that pullets laid equally well and maintained normal health on mash and grain rations containing 65 to 70 per cent of a single cereal grain. The Indiana Station[9] concluded that either wheat or corn was satisfactory with a masn made up of ground wheat, ground oats, meat scrap, and alfalfa leaf meal. The Wisconsin Station[10] obtained severe feather picking when yellow corn was fed as the only grain. Satisfactory growth may be obtained with rations consisting of either corn or wheat.[11]

The results have usually been improved where a variety of grains have been fed Corn, wheat, and oats, as grains, have been reported better than corn alone by the Ohio[12] and Kentucky[13] stations. The Missouri Station[14] obtained an increase in egg production when the percentage of wheat products was increased up to the point where the ratio between corn and wheat was equal. Experiments at Cornell[15] demonstrated that a laying ration, made up largely of a combination of wheat and corn, gave better results than rations composed largely of either grain alone. Better results were secured at the Oklahoma Station[16] where three grains were fed in the scratch mixture than where it was restricted to one.

COMMONLY USED POULTRY FEEDS*

A large variety of feeds are used in poultry rations The ones used most commonly are discussed herewith.

*Definitions used here, and inclosed in quotation marks, are those given in the Official Publication of the Association of American Feed Control Officials, Incorporated. 1954

ALFALFA PRODUCTS. "Alfalfa Meal is the product obtained by grinding alfalfa hay which is reasonably free of other crop plants, weeds, and mold. It must contain not more than 33 per cent of crude fibre."

"Alfalfa Leaf Meal is the ground product consisting chiefly of alfalfa leaves. It must be reasonably free of other crop plants and weeds and shall contain not less than 20 per cent crude protein and not more than 18 per cent of crude fibre."

The word "dehydrated" may precede the definition of alfalfa products, provided the product has been artificially dried.

Where alfalfa products are used in the mash, it is desirable to use the leaf meal or a screened product in order to reduce on the fiber. It will be noticed that the leaf meal, at its best, is high in this respect. Alfalfa meal[17] has been used widely in poultry rations and has shown benefits because it contains valuable nutrients. It is included primarily for its vitamin A and vitamin K values. It may also contribute appreciable amounts of the water-soluble vitamins. It is not palatable and consequently large amounts should not be used. The requirements for the nutrients can be met with amounts not over 5 per cent. There is no particular advantage in feeding larger amounts. On the other hand, the feeding of alfalfa meal has certain limitations. There may be some disadvantages such as the effect on the color of egg yolks and the increase in fiber and bulk which might affect growth and production.

Some experiments have reported a depression[18] in the growth of chicks due to a factor in alfalfa meal. Most of the reports indicate no depressed growth until more than 5 per cent is fed and usually much higher levels are necessary. On the other hand, higher levels frequently have not shown depression. The factor is believed to be a saponin which has hemolytic (i.e., red-blood-cell-dissolving) properties. This action is counteracted by cholesterol and other sterols.

Alfalfa meal is usually limited to 5 per cent in chick rations. With good dehydrated alfalfa the nutritive requirements for vitamins A and K can be met by including much less than 5 per cent in the ration. Mature chickens can tolerate much higher levels, in some cases as much as 10 per cent being fed. Turkeys apparently can efficiently utilize greater amounts than chickens.[19] Unfavorable results, whether caused by any specific harmful fraction, by increasing fiber and decreasing energy, or by the action of some other factors such as palatability, have been reported only with the higher levels of alfalfa, in many instances considerably above the commonly recommended maximum levels

BARLEY AND ITS PRODUCTS. Barley is used in poultry grain mixtures. It is not quite so palatable as wheat nor does it contain quite the desirable characteristics that wheat does. Except for its higher fiber, it compares very favorably with wheat in its composition.

"Rolled or Crimped Barley is heavy barley that has been rolled to desired thickness after tempering so as not to crumble. It shall contain not less than 90 per cent pure barley and not more than 10 per cent weed seeds or other foreign materials and not more than 6 per cent crude fiber."

"Ground Barley is the entire product obtained by grinding clean sound barley, containing not less than 90 per cent of pure barley and not more than 10 per cent of other grains, weed seeds, and other foreign material and not more than 6 per cent of crude fibre; provided that no portion of this stated 10 per cent of other grains, weed seeds, or foreign material shall be intentionally added."

Barley and ground barley are used quite extensively in regions where barley is grown. Ordinarily, ground oats and ground barley are used more or less interchangeably. Their compositions are comparable, except that barley contains much less fiber than ground oats. Ground barley should be fine ground when included in the mash.

Good results have been reported for barley[20] as a principal ingredient in poultry rations. Because of its low vitamin A value, when barley is used in place of corn, the ration must make special provision for this deficiency, usually by a liberal supply of alfalfa leaf meal or green food.

"Barley Feed is the entire by-product resulting from the manufacture of pearl barley from clean barley " Since the pearl barley is made up of most of the kernel, the feed consists of the outer portions of the grain. It contains too much fiber to be of value as a poultry feed.

"Barley Mixed Feed is the entire offal from the milling of barley flour from clean barley and is composed of barley hulls and barley middlings." It is also too bulky for poultry rations.

"Barley Hulls is the product consisting of the outer coverings of the barley." They are of little value for poultry.

BREWERS' PRODUCTS. "Malt Sprouts is the product obtained by the removal of the sprouts from malted barley together with the malt hulls, other parts of malt, and foreign material unavoidably present. It shall contain not less than 24 per cent of protein. The term 'Malt Sprouts' when applied to a correspond-

ing portion of other malted cereals shall be used in qualified form, as for example: 'Rye Malt Sprouts,' 'Wheat Malt Sprouts,' etc." They are a light, bulky feed, only moderately palatable, and would lighten the mash much the same as wheat bran.

"Brewers' Dried Grains is the dried extracted residue of barley malt alone or in mixture with other cereal grain or grain products resulting from the manufacture of wort." They are composed largely of barley. They are high in protein and fat but are rather shucky and contain considerable fiber.

DISTILLERS' PRODUCTS. "Corn Distillers' Dried Grains are obtained in manufacturing distilled liquors and alcohol from corn, or from a grain mixture in which corn predominates, by drying that portion of the whole stillage retained by screens."

"Rye Distillers' Dried Grains is the product obtain in the manufacture of distilled liquors and alcohol from rye, or from a grain mixture in which rye predominates, by drying that portion of the whole stillage retained by screens."

"Wheat Distillers' Dried Grains is the product obtained in the manufacture of distilled liquors and alcohol from wheat, or from a grain mixture in which wheat predominates, by drying that portion of the whole stillage retained by screens."

"Grain Sorghum Distillers' Dried Grains is the product obtained in the manufacture of distilled liquors and alcohol from grain sorghum, or from a grain mixture in which grain sorghum predominates, by drying that portion of the whole stillage retained by screens."

The distillers' dried grains are fairly high in protein and fat and, like the brewers' dried grains, are chaffy.

"Corn Distillers' Dried Solubles is the product obtained in the manufacture of distilled liquors and alcohol from corn, or from a grain mixture in which corn predominates, by condensing and drying the screened stillage obtained therefrom."

"Rye Distillers' Dried Solubles is the product obtained in the manufacture of distilled liquors and alcohol from rye, or from a grain mixture in which rye predominates, by condensing and drying the screened stillage obtained therefrom."

"Wheat Distillers' Dried Solubles is the product obtained in the manufacture of distilled liquors and alcohol from wheat, or from a grain mixture in which wheat predominates, by condensing and drying the screened stillage obtained therefrom."

"Grain Sorghum Distillers' Dried Solubles is the product obtained in the manufacture of distilled liquors and alcohol from grain sorghum, or from a grain mixture in which grain sorghum predominates, by condensing and drying the screened stillage obtained therefrom."

"Grain Sorghum Distillers' Dried Grains with Solubles is the product obtained in the manufacture of distilled liquors and alcohol from grain sorghum, or from a grain mixture in which grain sorghum predominates, by drying that portion of the whole stillage retained by screens to which condensed screened stillage has been added so that the final product contains not less than 3/4 of the solids content of the whole stillage."

"Corn Distillers' Dried Grains with Solubles is the product obtained in the manufacture of distilled liquors and alcohol from corn, or from a grain mixture in which corn predominates, by drying that portion of the whole stillage retained by screens to which condensed screened stillage has been added so that the final product contains not less than 3/4 of the solids content of the whole stillage."

"Rye Distillers' Dried Grains with Solubles is the product obtained in the manufacture of distilled liquors and alcohol from rye, or from a grain mixture in which rye predominates, by drying that portion of the whole stillage retained by screens to which condensed screened stillage has been added so that the final product contains not less than 3/4 of the solids content of the whole stillage."

"Wheat Distillers' Dried Grains with Solubles is the product obtained in the manufacture of distilled liquors and alcohol from wheat, or from a grain mixture in which wheat predominates, by drying that portion of the whole stillage retained by screens to which condensed screened stillage has been added so that the final product contains not less than 3/4 of the solids content of the whole stillage."

"Molasses Distillers' Condensed Solubles is the product obtained by condensing to a syrupy consistency the residue from the yeast fermentation of molasses after the removal of the alcohol by distillation."

"Molasses Distillers' Dried Solubles is the product obtained by drying the residue from the yeast fermentation of molasses after the removal of the alcohol by distillation."

Distillers' products and especially the dried distillers' solubles have increased in importance in poultry rations. They furnish protein, many of the vitamin B-complex factors, and pos-

sibly some unidentified factors. They have been shown to be satisfactory for growth, feed efficiency, and feather development, as well as for egg production and hatchability.[21]

Most of the experiments included 5 to 10 per cent of the distillers' dried solubles, although in some instances higher quantities have been fed. When distillers' dried grains with solubles were fed, a larger amount was used, usually 10 to 20 per cent of the ration.

In the feeding of distillery slop to chicks, the workers at the Kentucky Station[22] found that thin distillery slop proved unsatisfactory as a supplement to an all-mash ration but with thick distillery slop, containing 8.5 to 9 per cent solids, as much as $^4/_5$ of the corn in the mash could be replaced.

Other fermentation products,[23] such as molasses and grain butyl and ethyl fermentation solubles have been satisfactorily fed to poultry. Many of these have been particularly valuable as riboflavin supplements.

BUCKWHEAT AND ITS PRODUCTS. Buckwheat as a grain is of more or less local importance, being fed in those sections where it is grown. Buckwheat has certain undesirable characteristics such as the heavy husk which gives it a larger fiber content and the dark color of the kernel which makes it unattractive to the birds. It is not so palatable as corn or wheat, but is much the same as oats in this respect. Again it is usually used in the winter ration. There is greater difficulty in keeping it over summer, because it is likely to get musty in the bin. It is not a substitute for wheat. Except for the fiber content, its composition resembles corn more than wheat. When used in the grain mixture, it should not make up more than $^1/_4$ of the mixture. Sometimes it is hopper fed in addition to the regular scratch grain. Ground buckwheat may be used in the mash mixture, replacing ground oats.

"Buckwheat Middlings is that portion of the buckwheat grain immediately under the hull after separation of the flour. It shall contain no more hulls than are obtained in the usual process of buckwheat milling, and must not contain more than 10 per cent of crude fibre." A good grade of buckwheat middlings is a valuable fattening feed, producing good quality white flesh. They are high in protein and fat and can be used the same as wheat middlings.

"Buckwheat Feed is a mixture of buckwheat middlings and buckwheat hulls. It must not contain more than 30 per cent of crude fiber."

Maize is not sufficient alone as a feed for poultry, but where grown it must remain the principal element in poultry feeding. It can be fed heavily, however, when properly balanced.[26]

Some experiments indicate an advantage is using a larger amount of corn, and no gain in feeding a variety ration in place of a simple one composed largely of corn.[27]

Other experiments indicate an advantage in replacing some of the corn with other grains. On a corn-skimmilk ration, the Kentucky Station[13] reports better egg production when part of the corn is replaced by wheat or oats or a combination of the two. Heuser[15] found that a laying ration made up largely of a combination of wheat and corn gave better results than rations composed largely of either grain alone. Ohio[28] reports improvement in the ration when 20 per cent or more of corn was replaced with a like amount of oats. Prentice[29] indicated that maize meal, replacing Sussex ground oats in a laying ration, produced greater gain in body weight and a higher rate of egg production.

The California Station[30] concluded that a ration composed of a high proportion of corn, fed continuously during the first 18 months of life, produced a significantly higher laying-hen mortality than a similar ration in which a large part of the corn had been replaced by barley and alfalfa meal. Differences in mortality were primarily accounted for by an increase in pathological conditions of the reproductive tract, such as ruptured and flabby ova, occluded oviducts, reverse peristalsis, and prolapsus. The corn ration, when fed only during the rearing period or only during the first laying year, did not significantly increase either the laying-hen mortality or reproductive types of pathology, although heavier losses occurred than in the barley-fed lots. More rapid and earlier sexual maturity were produced by the corn ration. Surviving birds produced as many eggs in the corn-fed lots as in the barley-fed lots. Hence the differences in production index were entirely due to the differential mortality.

Jeffrey[31] concluded that the nutrition of the chicken during the growing period had a bearing on adult mortality and suggested that oats, wheat, and barley should be given preferred ratings over yellow corn in compounding rations, especially growing rations. He also called attention to the fact that yellow corn is deficient in the factor, resulting in smooth feathering in chickens, and produces oily and curly or rough feathering, in contrast to smooth and glossy feathering produced by oats, oat hulls, and wheat bran. It is suggested that cannibalism, particularly feather picking, is worse on corn diets because the birds are more in-

clined to pick at oily, curled feathers than at smooth, glossy ones.

Corn is recognized as one of our best fattening feeds and is used extensively in the fattening industry in this country. It has even been used exclusively as the cereal for this purpose.[22]

Yellow corn is preferable to the white corn because of its higher vitamin content, particularly of the vitamin A. Red corn with a yellow endosperm is equal to yellow corn in vitamin A activity. After the birds become accustomed to red corn, they will eat it readily.

The yellow corn gives yellow color to the flesh of the bird, which is desirable and preferable in poultry markets in this country. In England, where white color is desirable, fattening rations are made up very largely of fine ground oats, which, of course, helps to maintain white color in the carcass. Yellow corn produces a deeper color in the yolk. It also has a tendency to make white-plumaged birds creamy.

GRADES FOR CORN*

No. 1. Cool and sweet, not less than 55 pounds to the bushel, not over 14 per cent moisture; not more than 2 per cent foreign material and not more than 2 per cent of damaged corn; there shall be no heat damage.

No 2 Cool and sweet, not less than 53 pounds to the bushel, not over 15 5 per cent moisture, not more than 3 per cent foreign material and not more than 4 per cent damaged corn; not more than 0 1 per cent heat damage.

No. 3. Cool and sweet, not less than 51 pounds to the bushel, not over 17.5 per cent moisture; not more than 4 per cent foreign material and 6 per cent damaged corn, not more than 0 3 per cent heat damage

No 4. Cool and sweet, not less than 49 pounds per bushel, not over 19.5 per cent moisture; not more than 5 per cent foreign material and 8 per cent damaged corn; not more than 0 5 per cent heat damage

No 5. Cool and sweet, not less than 47 pounds per bushel, not over 21.5 per cent moisture, not more than 6 per cent foreign material and 10 per cent damaged corn, not more than 1 per cent heat damage

No. 6 Cool but may be musty or sour, not less than 44 pounds per bushel not over 23 per cent moisture, not more than 7 per cent foreign material and 15 per cent damaged corn, not more than 3 per cent heat damage.

Sample grade Sample grade shall be corn which does not come within the requirements of any of the grades 1 to 6, inclusive, or which has any commercially objectionable foreign color, or is heating, hot, infested with live weevils or other insects injurious to stored grain, or is otherwise of distinctly low quality

*Taken from U S D. A. Handbook of Official Grain Standards

Popcorn. The question of the use of popcorn often arises. Where popcorn waste has been tried, it has been found that it does not seem to be very palatable and hence would not be a wise inclusion in the ration.[33]

Sweet Corn. Dried sweet corn can be fed to poultry either as a grain or as the meal. The amounts that can be used will depend upon their consumption by the birds.

"Corn Meal is finely ground, unbolted corn."

"Corn Chop, Ground Corn, or Cracked Corn is the entire product made by grinding, cutting or chopping the grains of sound Indian corn, and may be fine, medium, or coarse. It must not contain more than 4 per cent of foreign material."

"Screened Corn Chop, Screened Ground Corn, or Screened Cracked Corn is the coarse portion of corn chop, ground corn, or cracked corn from which most of the fine particles have been removed. It must not contain more than 4 per cent of foreign material."

Corn meal or ground corn is one of the widely used ingredients of the poultry mash, having the same desirable qualities as listed for the grain. It has the desirable characteristic of not being sticky when mixed with water, and ordinarily will give a good physical condition to the mash mixture. Care must be taken in storing the meal because of heating.

"Corn Feed Meal is the fine siftings obtained in the manufacture of screened corn chop, screened ground corn, or screened cracked corn with or without its aspiration products added."

Since it is not a whole grain ground, there is likely to be considerable variation in this product. It often is a bulkier, chaffier feed because of the larger amounts of bran that it contains. It might also contain more fat because of germs that are lost in cracking. It can be satisfactorily used if it does not contain too much of the fiber.

"Corn Bran is the outer coating of the corn kernel, with little or none of the starchy part or germ." It consists mainly of cellulose and makes up about 6 per cent of the grain. As far as the composition is concerned, it does not differ widely from wheat bran. It does not contain the minerals that wheat bran does, has less protein, and more fiber. Poultry usually is not fed corn bran, although some of it could be fed in the same way as wheat bran, for lightening the ration. Corn bran has been reported as much better than rice bran, but decidedly inferior to corn meal.[34]

"Hominy Feed is a mixture of corn bran, corn germ, and a

part of the starchy portion of either white or yellow corn kernels or mixture thereof as produced in the manufacture of pearl hominy, hominy grits, or table meal, and shall contain not less than 5 per cent of crude fat. If prefixed with the words 'white' or 'yellow,' the product must correspond thereto."

The hominy products are thus made up of all the corn kernel, except part of the interior of the corn or endosperm. They are, therefore, composed of the bran, the germ, and part of the starchy portion of the kernel. Their composition compares favorably with that of corn meal. Hominy has a little more fiber and minerals, since part of the starch has been taken out. There is not much difference so far as the protein is concerned, but as it contains the germ it is higher in fat. The hominy can be used in much the same way as corn meal[35] and can be substituted pound for pound for the corn meal, where it is available at a price not to exceed that of corn meal. It is especially desirable for fattening, since it produces good-quality flesh and fattens quickly. Its use is limited because it is a by-product and is not readily available in large quantities. The yellow hominy products contain vitamin A and are preferable in that respect.

"Corn Germ Meal is ground corn germ cake."

"Corn Germ Cake consists of corn germ with other parts of the corn kernel from which part of the oil has been pressed and is the product obtained in the dry milling process of manufacture of corn meal, corn grits, hominy feed, and other corn products."

"Corn Oil Meal is ground oil cake or flakes. Its name must include one of the terms (hydraulic, expeller, or solvent extracted) to indicate the method of manufacture of the source material."

"Corn Oil Cake and Corn Oil Flakes consist of the corn germ from which most of the oil has been removed by hydraulic, expeller, or solvent extraction and are the products obtained in the wet milling process of manufacture of corn starch, corn syrup, and other corn products. For each product, the designating name must include a term (hydraulic, expeller, or solvent extracted) descriptive of the process of manufacture, and the product must correspond thereto."

These germ products, composed chiefly of the germ which makes up about 10 per cent of the grain by weight, are rich in fat and vitamins and are good feeds Usually they are more expensive than the other products and are not extensively used Corn oil meal has the valuable characteristic of being able to

absorb large quantities of liquids. When corn oil meal is saturated with liquids, it swells and thickens, enabling it to hold other feeds in a mixture in suspension. For this reason, corn oil meal is a very desirable ingredient in fattening rations.

"Corn Gluten Meal is that part of commercial shelled corn that remains after the extraction of the larger part of the starch and germ, and the separation of the bran by the processes employed in the wet milling manufacture of corn starch or syrup. It may or may not contain one or more of the following: corn solubles, corn oil meal."

"Corn Gluten Feed is that part of commercial shelled corn that remains after the extraction of the larger part of the starch and germ by the processes employed in the wet milling manufacture of corn starch or syrup. It may or may not contain one or more of the following: corn solubles, corn oil meal."

The corn gluten products are high in protein and are thus one of our vegetable protein concentrates (see Chap. 7). When made from yellow corn, they are also rich in vitamin A. Corn gluten meal has been reported to be six times as potent as yellow corn in vitamin A. *Gluten meal contains more protein and less fiber* than the gluten feed because the bran is not included in the former. In some cases, gluten has had an unfavorable effect upon the kidneys of the birds. It might be possible that in those cases there was not a proper balance of the rest of the ration or too much was fed. The gluten meal seems to be palatable and, where used in moderate amounts, will be satisfactory. The yellow pigments in corn gluten meal promote the desirable yellow coloring in the skin and shanks of the birds.

"Corn Grits or Hominy Grits is the product consisting of fine or medium sized, hard, flinty portions of sound Indian corn containing little or none of the bran or germ."

This is really the hominy used for human food and is ordinarily too expensive to use for poultry feeding, even for the young chicks. There is no advantage gained for poultry over straight cracked corn.

"Flaked Corn is the product obtained by running cracked corn which has been aspirated and properly tempered over smooth flaking rolls and subsequently dried and cooled."

"Ear Corn Chops is corn and cob chopped, *without the husk*, with no greater proportion of cob than occurs in the ear corn in its natural state." The Ohio[36] Station reported the following results when corn-and-cob meal was used as a substitute for ground shelled corn. During the first 8 to 10 weeks there was

TABLE 9. COMPOSITION OF CORN PRODUCTS*

	Fiber	Protein	Fat	N-Free Extract
Corn meal	2 0	8.6	3.9	69 3
Corn bran	9 2	9.7	7.3	62.0
Hominy feed	5.2	11.2	6 9	64.2
Gluten feed	7.6	25.5	2.7	48.8
Gluten meal	4.0	43.1	2.0	39.8

* Feeds and Feeding, Morrison, 1950. (See Table 3.)

little difference in mortality, but in general there was a slightly lower rate of growth. In the growing rations the corn-and-cob meal had a value equal to or greater than ground or whole shelled corn. With layers the corn gave slightly higher production, lower feed consumption, and higher returns. However, a noticeably better plumage condition, with little or no feather picking and cannibalism, was observed with the corn-and-cob meal.

COTTONSEED PRODUCTS. "Cottonseed Meal is a product of the cottonseed only, composed principally of the kernel with such portion of the hull as is necessary in the manufacture of oil; provided that nothing shall be recognized as cottonseed meal that does not conform to the foregoing definition and that does not contain at least 36 per cent of protein. Cottonseed meal shall be graded and classed as follows:

"Cottonseed Meal, Prime Quality—must be finely ground, not necessarily bolted, not have a sour or musty odor, reasonably bright in color, yellowish, not brown or reddish, free from excessive lint, and shall contain not less than 36 per cent protein. It must be designated and sold according to its protein content. Cottonseed meal with 36 per cent protein must be termed '36 per cent Protein Cottonseed Meal, Prime Quality,' and higher grades must be similarly designated as '43 per cent Protein Cottonseed Meal, Prime Quality,' etc

"Cottonseed Meal, Off Quality—Cottonseed meal not fulfilling the above requirement as to color, odor, or texture must be graded '36 per cent Protein Cottonseed Meal, Off Quality,' and higher grades similarly designated. It must be designated and sold according to its protein content."

"Solvent Extracted Cottonseed Flakes is the product obtained after solvent extraction of the oil from cottonseed kernels and such portions of the hull as is necessary in the manufacturing process."

"Solvent Extracted Cottonseed Meal is the product resulting from grinding solvent extracted cottonseed flakes. It must be designated and sold according to its protein content."

"Degossypolized Cottonseed Meal shall mean cottonseed meal from which the gossypol has been deactivated, so as to contain not more than 0.04 per cent free gossypol."

Cottonseed meals are vegetable protein concentrates and thus contain a large amount of protein. The chief deficiencies of cottenseed meal are lysine and vitamin B_{12}.[37] The lysine deficiency causes the production of white feathers in bronze turkeys. They also contain considerable fiber. The feeding results have been variable (see Chap. 7).

GRAIN SORGHUMS. Kafir Corn in its composition resembles corn quite closely, except that it contains slightly more fiber. As far as the kernel is concerned, it is of favorable size, has a light husk, has good color, and is relatively soft and palatable. It is used commonly in sections where it is grown. Its use in other sections is not very extensive because it usually costs more than the corn and does not have quite the feeding value. Still kafir corn or red milo can be used to advantage in poultry feeding.[38] In using kafir corn, the lighter, namely the white, or yellow round kernels of the kafir group are desirable because they contain very little of the tannin or bitter property found in darker kernels.

The sorghums are likely to be deficient in vitamin A and hence must be supplemented with green food or some source of this vitamin. When thus supplemented, kafir or hegari may replace yellow corn.[39] It has also been reported that grain sorghum[40] can replace wheat and other grains in poultry rations. The Oklahoma Station[16] reports that feterita and hegari were not so good as yellow corn, and that kafir is more efficient than darso, but that both could be fed. Mitchell[41] reported that the grain sorghum hegari, in starting rations, showed poorer growth and higher mortality and produced white-shanked birds. The palatability of the ration was affected. Fronda, Zialcita, and Basio[42] concluded that broom corn seeds were not so palatable or so efficient for egg production as corn grains. Ackerson and coworkers[43] reported that kalo could be substituted for corn in an otherwise complete ration for growing chicks, but that the instances of cannibalism were confined to the kalo-fed lot. McClymont[44] concluded that grain sorghum should not make up more than 15 to 25 per cent of the ration as higher levels depress growth and increase mortality.

CLASSIFICATION OF GRAIN SORGHUMS

- Kafir
  - Seeds white—round
    - White kafir
    - Blackhull kafir
- Durra
  - Seeds white—flattened
    - White durra
    - Blackhull durra
  - Seeds yellowish or reddish—slightly flattened
    - Yellow milo
    - Brown durra
- Broom Corn
  - Seeds reddish brown—round
    - Broom corn
  - Seeds white to buff—round
    - Shallu
  - Seeds white, brown or red—round
    - Kowliang

Kafir Meal. Its qualities are the same as kafir grain, and would be used in the ration similarly to corn meal.

LINSEED PRODUCTS. "Linseed Oil Meal is the product obtained by finely grinding the cake, chips, or flakes, according to the process employed, in the production of linseed oil. It must be designated and sold according to its protein content, and its name must include one of the terms 'hydraulic,' 'expeller,' or 'solvent extracted' to specify the method of manufacture of the source material."

"Linseed Feed is the product obtained by mixing one or more linseed oil meals with flaxseed screenings oil feed with or without other flaxseed by-products. It must be designated and sold according to its protein content."

Linseed oil meal is quite laxative, probably because of the oil. It is also very sticky when moistened, which renders it unpalatable. Both these characteristics indicate that, where it is used in the mash, the quantity needs to be very much restricted. Where it is included, probably not more than 5 per cent of the mash should be made up of this product. Oil meal is used as a basis for a good many of the so-called tonics. The protein of oil meal is of low biologic value. (See Chap. 7.)

MILLET. Millet is not a valuable feed for poultry. It has a high fiber content. It is often included in small chick grain mixtures for its appearance. It is shiny and very attractive, but because of its hard, heavy husk it often passes through the digestive

tract without even being broken down. Besides, it is usually rather expensive. The kernel is too small for the feeding of mature birds.

Proso, also called broom corn millet and hog millet, belongs in the group of millets cultivated for grain production. The seeds are very hard and have a high fiber content. It is very similar to buckwheat in composition and feeding value.

The feeding value of proso millet has compared favorably with that of corn in starting, growing, and laying rations[45,46] as well as in the ration for growing turkeys.[47]

MINERALS. Common Salt is sodium chloride with impurities not exceeding commercial grade.

"Iodized Salt is common salt (NaCl) containing not less than 0.007 per cent of iodine uniformly distributed."

Salt functions in various ways.[48] This may have some bearing upon the levels recommended. Cereals and cereal by-products are low in sodium. Salt helps to supply sodium and chlorine. Poultry rations to which a small amount of salt was added have given better growth and more efficient utilization of food as well as more satisfactory egg production and better body weight. It has also been reported that salt appeared to improve the utilization of dietary nitrogen.

It has been frequently noted that high salt diets increase the water consumption which has an effect on the consistency of the droppings and results in the litter having to be changed more frequently.

Salt has also been recommended by the Wisconsin Station[49] as a means of preventing cannibalism. The treatment consisted in dissolving a tablespoonful of salt in each gallon of drinking water for one forenoon, and three days later repeating the treatment for another half day.

Too much salt is toxic (see Chap. 11). Much more salt can be fed than is necessary. The Wisconsin Station[50] reported that 5 per cent of salt in the ration is more than is desirable; that 2 per cent is not injurious; that birds getting more than 1 per cent of salt in the ration consumed more than a normal amount of water, with the result that the litter has to be changed more frequently. The Illinois Station[51] indicated that chickens could be raised from 9 to 21 weeks on rations containing as much as 8 per cent of salt, with no apparent detrimental effect on their condition. The Maryland Station[52] found that mortality was not excessive until the level of salt in the ration was greater than 5 per cent by weight and that chicks were able to endure salt

levels as high as 30 per cent for short periods of time.

The amount of salt that is required may be influenced by a number of factors. There seem to be some interrelationships[53] between salt and certain minerals such as potassium, calcium, phosphorus, and manganese as well as the nature of the feed ingredients. Because of some of the possible disadvantages it is desirable not to add too much salt to poultry rations.

Phosphorus Carriers. It is frequently necessary to increase the phosphorus content of the ration, particularly when the amounts of meat scrap and fish meal are limited. It is possible to supply phosphorus in a number of forms.

"Steamed Bone Meal is the dried, ground product suitable for animal feeding obtained by cooking bones with steam under pressure."

"Special Steamed Bone Meal is the dried, ground product suitable for animal feeding, obtained by cooking dried bones after the removal of grease and meat fibre with steam under pressure in the process of obtaining gelatin or glue."

"Bone Charcoal or Bone Black is the product obtained by charring bones in closed retorts. It shall contain not less than 14.7 per cent of phosphorus (P)."

"Spent Bone Black is the product resulting from the repeated charring of bone charcoal or bone black after use in clarifying sugar solutions. It shall contain not less than 11.5 per cent of phosphorus (P). The label shall show a guarantee for calcium (Ca) and phosphorus (P)."

"Bone Ash is the ash obtained by burning bones with free access of air, and containing a minimum of 15.3 per cent of phosphorus (P). The label shall show a guarantee for calcium (Ca), and phosphorus (P)."

"Defluorinated Phosphate includes either calcined, fused, or precipitated calcium phosphate. It shall contain not more than one part of fluorine (F) to 100 parts of phosphorus (P) The minimum percentage of calcium (Ca) and phosphorus (P) and the maximum percentage of fluorine (F) shall be stated on the label. The term 'Defluorinated' shall not be used as a part of the name of any product containing more than one part of fluorine (F) to 100 parts of phosphorus (P)."

The inorganic phosphorus carriers vary considerably in their availability.[54] Bone meals, defluorinated phosphates, mono, di-, and tricalcium phosphates, orthophosphates, and Curacao Island phosphate showed generally satisfactory availability. Phosphate rock, phosphate slag, and metaphosphates were generally in-

ferior. "Colloidal" phosphate and pyrophosphates were poor in availability.

Calcium Carriers. Most rations need some addition of calcium. It can be provided in various forms.

"Calcite, Ground Limestone, Chalk Rock, Precipitated Chalk, Oyster Shell Flour, Shell Flour, and Precipitated Calcium Carbonate are acceptable sources of calcium carbonate. They shall in each instance be true to name and shall contain not less than 33 per cent calcium (Ca). They shall be declared as ingredients only by the names listed above.

"Calcium Carbonate is a product containing not less than 38 per cent calcium (Ca)."

"Magnesium Limestone or Dolomitic Limestone is acceptable as a source of magnesium and calcium carbonates. The terms are synonymous and designate a native mineral composed of mixtures of magnesium carbonate ($MgCO_3$) with calcium carbonate ($CaCO_3$). It shall contain not less than 10 per cent magnesium (Mg) and shall be declared as an ingredient only by one of the names listed above."

A number of workers[55] have shown that in rations for chicks the various forms of calcium salts are available for bone formation. For eggshell formation, the carbonate form has proved most effective. Calcium phosphate and rock phosphate[56] have been shown to be definitely inferior as a source of calcium for laying hens.

Most of the forms of calcium carbonate have proved satisfactory as long as they did not contain too large amounts of magnesium, such as is found in dolomitic limestone.[57] Oystershells have been looked upon as the standard for laying hens. Other substances that have been used satisfactorily for this purpose are limestone,[58] marl,[59] mussel shells,[60] coquina shell,[61] cockle shell,[62] coral sand,[63] clam shells,[64] and eggshells.[65]

OATS AND THEIR PRODUCTS. Oats make a desirable grain for poultry feeding, but they should be restricted to plump heavy oats. For poultry feeding, they should weigh 40 pounds or better to the bushel. Light oats are practically valueless. Even with a heavy oat, there is a large amount of husk or fiber, constituting on the average about one-third of its weight. A big difference is found in the amount or proportion or thickness of the husk in different varieties. Dodd and Telford[66] report a variation in the proportion of husks or "hulls" ranging from 20.1 to 45.7 per cent. The fiber content was reported as ranging from 8.5 to 14 per cent. Even in the heavy, favorable oats there is a high fiber

content, usually about 10 per cent. The thin-hulled varieties should be chosen. The kernel itself is a desirable feed so that if the husk is taken away, the kernel that is left makes a very good feed. Some feeders say that oats seem to have a stimulating effect upon the nervous system. They are not so palatable as wheat or corn, which are usually eaten first. For that reason, oats are looked upon by some feeders as an indicator of the fowl's appetite.

To the mature birds, the heavy oats and clipped oats are ordinarily fed. However, hulled oats or oat groats of larger size are often fed, although they probably should not be included if they increase the cost materially. The hulled products as pinhead oats, oat groats, or oat flakes are the forms fed to chicks.

Because of the higher fiber content, oats should not compose more than 1/3 of the scratch grain. Ohio[28] reported that the ration was improved when 20 to 40 per cent of corn was replaced with a like amount of oats. There was practically no difference according to the form in which they were fed. Feeding whole oats, mixed with the all-mash mixture, was the easiest and least expensive way of feeding this grain, although a few more eggs were secured when finely ground oats were fed. The difference did not pay for the cost of grinding. With the free choice system of feeding whole oats, troubles such as feather picking, cannibalism, and pick-outs largely disappeared. The time and care required for germinating oats did not seem to be justified by the results obtained.

The results of experiments at the Western Washington Experiment Station[67] show that the cannibalism-preventing properties of oats is due to the fiber fraction of the oat hulls.

When fed as the exclusive grain in the ration, experiments at the Iowa Station[68] showed that oats ranked first for poultry feed in comparison with corn, wheat, and barley. The chicks grew faster and feathered more rapidly, there was less mortality, and cannibalism and feather picking were reduced. It was suggested that up to 40 per cent, or perhaps even more, of the ration of the growing chick, the laying hen, and the turkey could be made of oats, when the quality is good and the price justifies it.

The results of feeding experiments in Germany[69] and Australia[70] indicate that oats can be used in place of wheat, as grain food for laying hens. The digestible foodstuffs in oats can be utilized in the same way as those in wheat. Oat feeding will not be uneconomical when the cost of five parts of oats is the same as four parts of wheat. Care should be taken, however, to use,

as far as possible, full-grain, heavy, and fine-husk oats.

The South Dakota Station[71] has also shown that whole or ground oats may be used quite extensively in growing rations for turkeys from 12 to 28 weeks of age. As high as 80 per cent oats were fed.

"Oat Groats are the kernels produced from cleaned and dried oats in the process of manufacturing oat meal."

"Hulled Oats or Undried Oat Groats are the kernels produced from the undried grain in the process of hulling oats."

Pinhead oatmeal consists of oat groats, usually of small oats, so that we have the whole oat kernel. Steel-cut oats consist of larger oat groats that have been cut into several pieces by means of steel knives. Clipped oats are oats which have had the end or tip of the hull broken off. In this process part of the husk or fiber is removed and usually also the light oats are removed. Thus clipping makes the oats a better product for poultry feeding. Frequently oat flakes are used in chick starters.

Some poultrymen have reported trouble from chicks "pasting up behind" with such feeds. In that case the chick has probably picked out the oats. In rats restricted to an oat diet one of the physiological effects reported is pasty feces.

GRADES FOR WHITE OATS*

No. 1. Cool, sweet, not less than 32 pounds to the bushel, not less than 98 per cent sound; with not more than 0.1 per cent heat damage, 2 per cent foreign material, 2 per cent wild oats, or 2 per cent of other color oats.

No. 2. Cool and sweet, may be slightly stained, not less than 29 pounds to the bushel, not less than 95 per cent sound; with not more than 0.3 per cent heat damage, 2 per cent foreign material, 3 per cent wild oats, or 5 per cent of other color oats.

No. 3. Cool and sweet, may be stained, or slightly weathered, not less than 26 pounds to the bushel, not less than 90 per cent sound; with not more than 1 per cent heat damage, 3 per cent foreign material, 5 per cent wild oats, or 10 per cent of other color oats.

No. 4. Cool, may be musty, weathered, or badly stained, not less than 23 pounds to the bushel, not less than 80 per cent sound; with not more than 6 per cent heat damage, 5 per cent foreign material, 10 per cent wild oats, or 10 per cent of other color oats.

"Oat Chop, Ground Oats, Pulverized Oats, Crushed Oats, or Crimped Oats consists of the entire product made by chopping, cutting, grinding, crushing, or crimping whole oats. It shall contain not more than 10 per cent of other grains, weed seeds, and other foreign material."

*Taken from U.S.D.A. Handbook of Official Grain Standards.

Ground oats should be included in restricted amounts since they are a light, bulky food, high in fiber. Ordinarily, they should not constitute more than 20 or 25 per cent of the mash. The Indiana Station[72] reports that oats proved to be an efficient substitute for bran and middlings in rations for chicks when up to 30 per cent ground oats were used in place of 15 per cent each of wheat bran and wheat middlings. They should be ground fine enough so as to prevent picking over by the birds. The hammermill process of grinding is preferable. Crushed oats are not so desirable as ground oats because of their physical make-up. They give a coarseness to the mash which might encourage the hens to pick it over.

"Oat Middlings is the product consisting of the floury portions of the oat groat obtained in the milling of rolled oats."

"Oat Shorts is the product consisting of the covering of the oat grain lying immediately inside the hull, being a fuzzy material carrying with it considerable portions of the fine floury part of the groat obtained in the milling of rolled oats."

PEANUTS are not used as such for poultry, chiefly because they are too expensive. For mature turkeys of 20 pounds or more, the feeding of peanuts has been suggested as possible for about 1 month prior to marketing.

"Peanut Cake is the product obtained after the extraction of part of the oil by pressure or solvents from peanut kernels as produced under reasonable milling conditions. It must be designated and sold according to protein content."

"Peanut Meal is ground peanut cake provided that nothing shall be recognized as such that contains more than 11 per cent crude fiber. It must be designated and sold according to its protein content." It contains considerable protein and can be used satisfactorily where the price warrants its use. (See Chap 7.)

PEAS. Peas are not used very extensively in poultry feeding chiefly because they are usually too expensive When price is not a factor, there is no reason why they should not be included in the ration. They contain a large amount of protein Where peas are grown in combination with other grains, such as oats and barley, the mixture can be used in the scratch grain, although it would be better to grind the mixture and use it as a mash ingredient. Whole peas are used in pigeon feeds since pigeons seem to relish them.

RICE AND ITS PRODUCTS. Rice is not used to any extent in feeding poultry, but it is sometimes included in chick grains. It has no special nutritive value It is sometimes fed as a regu-

lator for bowel trouble. Diarrhea can frequently be relieved by feeding rice which has been boiled nearly dry in milk.

"Rice Bran is the pericarp or bran layer of the rice, with only such quantity of hull fragments as is unavoidable in the regular milling of rice."

"Rice Polishings is a by-product of rice obtained in the milling operation of brushing the grain to polish the kernel."

"Ground Rough Rice is ground rice from which the hull has not been removed or ground paddy rice."

Brewer's Rice consists of the small and cracked polished grains.

Experiments conducted at the Arkansas, California, Hawaii, and Louisiana agricultural experiment stations[73] show that rice products can be included in both the laying and growing rations of chickens with satisfactory results, provided a good source of vitamin A is furnished as a supplement to the rice feeds. Rice by-products, with a good vitamin A supplement, can be used as a satisfactory substitute for corn, wheat, oats, and the products of these grains in the laying and growing rations of chickens, when the relative price of these feeds justifies such a substitution. Brewer's rice can substitute for corn. Rice bran can be used in place of wheat by-products and rice polishings instead of ground oats.

RYE. Rye is one of the least-used grains in poultry feeding. It has good composition, resembling wheat, but it does not seem to be palatable, owing perhaps to the hardness of the kernels. Rye which was infected with ergot fungus has sometimes caused diarrhea in the poultry to which it was fed. Where it is not infected, there is no reason why some rye should not be used. Rye is frequently sown as a cover crop for poultry yards, for the hens seem to be able to eat the sprouted rye without harm.

Various by-products are also obtained in the milling of rye flour, such as rye feed, rye red dog, rye low-grade feed flour, rye middlings, and rye flour middlings, which are good feeds but are not used in poultry feeding, probably because of the prejudice against rye.

"Rye Feed is a by-product obtained in the usual process of the milling of rye flour from cleaned and scoured rye grain, consisting principally of the mill run of the outer covering of the rye grain and the germ with small quantities of flour and aleurone, and must not contain more than 9.5 per cent of crude fibre."

"Rye Red Dog is a by-product obtained in the usual process

of the milling of rye flour, consisting principally of aleurone with small quantities of rye flour and fine rye bran particles and must not contain more than 3.5 per cent crude fibre."

"Rye Low-Grade Feed Flour consists principally of rye flour and small quantities of aleurone and fine rye bran particles and must not contain more than 1.5 per cent of crude fibre."

"Rye Middlings consists of rye feed and rye red dog combined in the proportions obtained in the usual process of milling rye flour and must not contain more than 8.5 per cent of crude fibre."

"Rye Flour Middlings consists of rye feed, rye red dog, and rye flour combined in the proportions obtained in the milling of rye flour and must not contain more than 5 per cent of crude fibre."

Results of feeding rye in Germany[74] show that hens like food with a high percentage of rye (25 per cent in the mash and 50 per cent in the grain), that it is not harmful to the health of the birds, and produces good laying results. Experiments at Wisconsin[75] indicate that rye is unsatisfactory for young chicks, causing trouble with "sticky" droppings, but that it may be used in the ration for growing pullets and laying hens. For the pullets, not more than 30 per cent and, for mature birds, not more than 45 per cent rye should be fed. Wyoming[76] reports that rations containing 20 per cent of rye or less, when substituted for other cereal grains, were found to be practical for chicks. Higher levels caused a laxative condition.

When rye was fed to hens, there was little difference in egg production among the lots fed barley, rye, and oats. The hens fed rye produced eggs with the flattest yolks and watery albumen. The rye had a laxative effect upon the hens but did not appear to injure their health.

In a 9-month experiment with Leghorn pullets, satisfactory results were obtained when 15 or 30 per cent of rye bran replaced ground cereals in the mash. However, a maximum of 20 per cent is recommended.

The Nebraska[77] Experiment Station found that chicks which were fed ground wheat made better gains than chicks fed ground rye when these grains furnished 25 per cent of the protein of the ration.

SOYBEANS AND THEIR PRODUCTS. Soybeans are not fed to any extent to poultry. They are a vegetable protein concentrate but are not so valuable as the soybean oil meal.

"Ground Soybeans is the product obtained by grinding whole soybeans without cooking or removing any of the oil."

"Expeller Soybean Oil Chips is the product obtained after expressing part of the oil from soybeans by crushing, cooking, and mechanical pressure using an expeller, screw press, or any other mechanical press. It shall be designated and sold according to its protein content."

"Expeller Soybean Oil Meal is the product resulting from grinding expeller soybean oil chips. It shall be designated and sold according to its protein content."

"Hydraulic Soybean Oil Cake is the product obtained after expressing part of the oil from soybeans by crushing, cooking, and hydraulic pressure. It shall be designated and sold according to its protein content."

"Hydraulic Soybean Oil Meal is the product resulting from grinding hydraulic soybean oil cake. It shall be designated and sold according to its protein content."

"Solvent Extracted Soybean Flakes is the product obtained after extracting part of the oil from soybeans by the use of solvents. It shall be designated and sold according to its protein content."

"Solvent Extracted Soybean Oil Meal is the product resulting from grinding solvent extracted soybean flakes. It shall be designated and sold according to its protein content."

"Dehulled Solvent Extracted Soybean Flakes is the product obtained after extracting most of the oil from dehulled soybeans by cracking, heating, flaking, and the use of solvents. After extraction of the oil the product is cooked. It shall contain not more than 3 per cent crude fiber and shall be designated and sold according to its protein content."

"Dehulled Solvent Extracted Soybean Oil Meal is the product resulting from grinding dehulled solvent extracted soybean flakes. It shall contain not more than 3 per cent crude fiber and shall be designated and sold according to its protein content."

Soybean oil meal is the most widely used vegetable protein concentrate in poultry rations (see Chap. 7).

SUNFLOWER SEEDS. Sunflower seeds are not ordinarily used to any extent in poultry feeding because of the very high fiber content and because they are usually too expensive.

Tests made of the value of sunflower seeds, grown in England[78] for poultry feed, found them entirely satisfactory and an excellent substitute for the cereal grains. The seeds were quite digestible, gave more energy than the cereals on an equal-weight basis, and were palatable when fed to the flock under competitive conditions.

When sunflower seeds are fed, they are frequently included in the ration because of the high fat content. Thus their use is usually restricted to the molting season, since it is thought by some that feather growth is aided. They probably help to make the feathers oily or glossy. They are commonly added to commercial mixtures to improve their appearance; usually only 1 to 2 per cent is used.

Sunflowers are frequently grown in the poultry yards to provide shade. They will also help to keep the ground in condition since they are rank feeders. Where they are thus grown in yards, the birds are allowed to harvest the seeds as they become ripe.

VITAMINS. "Cod Liver Oil is the oil obtained from the livers of *Gadus morrhuae* or other species of the family Gadidae, either or both. It must contain not less than 385,900 U.S.P. units of vitamin A per pound (850 units per gram) and not less than 29,510 International chick units of vitamin D per pound (65 units per gram)."

"D-Activated Animal Sterol is a product which is obtained by activation of a sterol fraction of animal origin with ultraviolet light and other means. For label identification it may be followed with the parenthetical phrase ('Source of Vitamin D_3')."

"Vitamin A and D Feeding Oil is either fish or fish liver oil or a blend of two or more of the following: vitamin A and/or D concentrate, synthetic vitamin D, fish liver oil, fish oil, marine animal oil, or edible vegetable oil. The vitamin potency shall be stated in International chick units of vitamin D and U.S P. units of vitamin A per pound."

"Vitamin D Feeding Oil is either fish or fish liver oil or a blend of two or more of the following: vitamin D concentrate, synthetic vitamin D, fish liver oil, fish oil, marine animal oil, or edible vegetable oil. The vitamin potency shall be stated in International chick units of vitamin D per pound"

"Vitamin A Feeding Oil is either fish or fish liver oil or a blend of two or more of the following: vitamin A concentrate, fish liver oil, fish oil, marine animal oil, or edible vegetable oil. The vitamin potency shall be stated in U.S.P. units of vitamin A per pound."

"Riboflavin Supplement is a feeding material used chiefly for its riboflavin content and shall contain not less than 200 milligrams of riboflavin per pound The label shall bear a statement of origin."

"Vitamin B_{12} Supplement is a feeding material used for its

vitamin B_{12} activity. It shall contain a minimum vitamin B_{12} activity of 1.5 milligrams per pound. The term shall not be applied to products for which there are accepted names and definitions."

"Vitamin E Supplement is a feeding material used for its vitamin E activity. It shall contain a minimum vitamin E activity equal to 10,000 International units of vitamin E per pound. The label shall bear a statement of vitamin E activity in terms of International units of vitamin E per pound."

WHEAT AND ITS PRODUCTS. Wheat is a very good grain for poultry feeding. It is rated by some people as the ideal poultry feed. Because of the demand for wheat for human food, its use has been largely discontinued for other farm animals. Its use for poultry, however, has been continued, probably because it is well adapted to them and because fowls are efficient producers. Wheat has a large number of desirable characteristics. It is the most palatable grain and is adapted to the feeding of fowls because of its favorable size and color and its low fiber content. It compares very favorably with corn in its composition, containing slightly more of the protein and just a little bit more of the fiber. On account of its high protein content it has a slightly narrower nutritive ratio than corn.

Even though wheat has favorable characteristics for poultry feeding, the amounts that are used have been decreasing, probably because of the price. Wheat is more favorably adapted to human consumption than corn and in that respect, where it is used in animal feeding, it is competing with a higher-priced market. For that reason, its use probably will not increase, but is likely to decrease in the future.

Wheat, like corn, can make up a very large proportion of the ration, but it cannot be fed in so large proportions as corn.[79] There is some evidence to indicate that wheat, when fed very heavily, does have detrimental results, probably due to the deficiency of vitamins. In early tests carried on at Ohio[12] there was very little difference in production between corn and wheat rations, but there was a difference in the mortality of the two lots. The corn group lost 8 per cent while in the wheat group the mortality amounted to 52 per cent. In all probability vitamin A was the limiting factor. In feeding wheats of different protein content[80] to chicks it was shown that the differences in growth response were primarily due to differences in the relative proportions of protein contributed and to the differences in the lysine content. McClymont and Hart[81] report that high wheat

rations for White Leghorn pullets require a supplement of animal protein, oil meal, riboflavin, and green feed.

Normally, wheat should probably not compose more than 50 to 60 per cent of the laying ration, although larger amounts have been fed satisfactorily. In an experiment conducted at Cornell,[15] a laying ration composed largely of wheat gave better results than a laying ration composed largely of corn. The rations containing wheat resulted in higher grain and total feed consumption, owing to a preference for wheat over corn. The chief factors influencing the results were the nutritive value of wheat and wheat by-products and increased feed intake due to the palatability of the wheat.

In growth trials, normal growth cannot continue long on a heavy wheat diet unless it is properly supplemented. The Indiana Station[82] reported on the substitution of 40 per cent of ground wheat for ground yellow corn in broiler rations. When the ration contained 3 per cent of alfalfa leaf meal, the advantage was in favor of corn. When the ration contained 5 per cent of alfalfa leaf meal, growth was practically the same.

There are many different kinds and varieties of wheat. There is probably not much difference in their feeding values, but practice shows that the soft, plump wheats are more palatable than the harder varieties. Under most conditions, the hen will consume enough feed for her needs, but when food consumption is down this might be a factor to be considered. Goodearl[83] reported that shrunken wheat (40 pounds to the bushel) was not inferior to plump wheat (60 pounds to the bushel) for laying hens when used in equal amounts. However, McArdle[83] reported that as the weight per bushel of wheat fell, egg production decreased.

It is thought by some[84] that wheat may be concerned with the incidence of pullet disease or blue comb. However, all wheats do not seem capable of producing this result. Yet trouble has frequently been reported as the result of feeding new grain. Although the feeding of new wheat is not always fatal and may not prove even noticeably injurious, it seems best not to feed new wheat or other grains, especially those with high moisture content. Birds which are affected show profuse diarrhea, darkened comb, and decided enteritis. The digestive system is usually full of fermented wheat.

Grades of Wheat. There are different classes of wheat, such as hard red spring wheat, durum wheat, hard red winter wheat, soft red winter wheat, and white wheat. Each class has six different grades, the first four of which must be cool and sweet.

The requirements vary with the classes, but the highest grade always has the greatest weight per bushel, the least moisture, and the smallest amount of damaged kernels, heat damage, and foreign material. (For details see U.S.D.A. Handbook of Official Grain Standards.)

Feed Wheat usually has reference to a grade of wheat not accepted for milling purposes. There are several possible reasons for its not being accepted. It may be that the kernels are not large and plump enough; it may be that it contains a large amount of foreign matter, cockle, or other weed seeds; it may be that mold is present or there is too large a percentage of sprouting. Thus feed wheat is a variable product. It may be a favorable feed, or it may be one that is unsatisfactory.

Salvage Wheat ordinarily refers to wheat that has been in an elevator fire. It may be burnt or scorched, and it may be musty because of being soaked with water. If it is not musty, it can be used for poultry feeding; if it is musty, the chances are that it will be unsatisfactory.

Wheat Screenings are ordinarily made up of small, cracked, and shrunken kernels and other foreign material and weed seeds. Wheat screenings are ordinarily made up of refuse of better grades of wheat. Therefore wheat screenings are not considered of much value in poultry feeding, unless they are made up primarily of the smaller and cracked grains.

Elevator Screenings are usually made up primarily of weed seeds and the smaller kernels sifted out. The weed seeds usually are made up of various mustards and cockle. The mustards are usually bitter and, when present in any considerable amount, have a toxic effect by causing irritation of the mucous membrane of the intestines.

Sulfured Wheat is wheat that has been put through a process of bleaching by wetting the wheat, subjecting it to the fumes of sulfur dioxide, and then drying to remove the moisture. Usually the red or durum wheat is thus processed to improve the appearance. Its effect upon the feeding value is not known, but it probably has very little if any effect.

Feeding Wheat. The practice of feeding wheat in the bundle, that is, throwing a sheaf of wheat into the pen and letting the hens thresh it for themselves, can be followed but usually is not reliable because it is hard to tell just how much wheat is being fed. It is difficult to know what amount of grain the birds are getting, and the tendency is to underfeed rather than overfeed. Besides, there is a rapid accumulation of straw which must be

removed, frequently before it is necessary to do so for sanitary reasons.

Wheat By-Products. Various by-products of wheat obtained in the manufacture of flour are available for animal feeding. The wheat kernel consists of three rather distinct parts: the outer layers of bran comprise about 16 per cent of the weight of the kernel, the endosperm about 82 per cent, and the germ about 2 per cent. In the milling process much of the bran is removed in layers or flakes, but some is broken into fine particles and becomes mixed with the flour. The by-products removed successively from the outside of the kernel and their approximate percentages are: bran 11 per cent, shorts or middlings 11 per cent, and red dog flour 5 per cent. The remainder, or 72 per cent of the kernel, consisting mostly of starch, is converted into flour. The wheat germ may be included in the by-products or collected separately. The oil may be expressed from the germ and sold as wheat germ oil. The bran layers and germ contain most of the protein, vitamins, fats, and minerals; the endosperm is mostly starch. Since the outer layers contain most of the ash, fiber, and protein, the wheat by-products contain more of these nutrients and less total nutrient than whole wheat.

"Wheat Bran is the coarse outer covering of the wheat kernel as separated from cleaned and scoured wheat in the usual process of commercial milling." Bran is chaffy and bulky and contains considerable fiber. It is also slightly laxative in its nature, owing to its content of crude fiber and pentosans.[85] Its digestibility is low, which, combined with the fiber content, makes it low in total available nutrients. The ash content or mineral content of wheat bran is considered favorable in furnishing phosphorus and manganese.

"Wheat Standard Middlings consist of fine particles of wheat bran, wheat germ, wheat flour, and some of the offal from the 'tail of the mill.' This product must be obtained in the usual process of commercial milling and shall contain not more than 9.5 per cent of crude fibre."

"Wheat Brown Shorts consists of fine particles of wheat bran, wheat germ, and wheat flour and some of the offal from the 'tail of the mill.' This product must be obtained in the usual process of commercial milling and must not contain more than 7.5 per cent of crude fibre."

"Wheat Gray Shorts, Wheat Gray Middlings, or Wheat Flour Middlings consists of the offal from the 'tail of the mill' together with some fine particles of wheat bran, wheat germ, and

wheat flour. This product shall be obtained in the usual process of commercial milling and shall contain not more than 6.0 per cent of crude fibre."

"Wheat Red Dog, Wheat White Shorts, or Wheat White Middlings consists of the offal from the 'tail of the mill' together with some fine particles of wheat bran, wheat germ, and wheat flour. This product shall be obtained in the usual process of commercial milling and shall contain not more than 4.0 per cent of crude fibre."

"Wheat Feed Flour consists principally of wheat flour together with fine particles of wheat bran, wheat germ, and the offal from the 'tail of the mill.' This product shall be obtained in the usual process of commercial milling and shall contain not more than 1.5 per cent of crude fibre."

In middlings, we have the standard type and the flour type. These types differ in composition and also in texture because the standard middlings contain a larger proportion of bran particles than the flour middlings.

Wheat middlings and shorts also have a slightly laxative effect. They are sticky when mixed with water and therefore should not constitute large proportions of the feed.

Red dog flour is the product used in poultry feeds. It is low in fiber and has much the same characteristics as flour middlings. It is used to quite an extent in fattening rations.

"Wheat Mixed Feeds consists of the coarse outer covering of the wheat kernel, fine particles of wheat bran, wheat germ, and wheat flour, and the offal from the 'tail of the mill.' This product shall be obtained in the usual process of commercial milling and shall contain not more than 9.5 per cent of crude fibre."

"Wheat Germ Meal consists chiefly of wheat germ together with some bran and middlings or shorts. It shall contain not less than 25 per cent of protein and 9 per cent of fat."

"Wheat Germ Oil Cake is the cake secured in the removal of part of the oil from wheat germ meal and shall contain not less than 29 per cent of protein."

"Wheat Germ Oil Meal is ground wheat germ oil cake."

Part of the wheat germ is sometimes removed so that the by-products contain relatively less of this portion of the grain. It is a valuable part of the grain since several of the vitamins of wheat are located chiefly in this portion. It is desirable that the germ be left in the wheat by-products as otherwise a deficiency of vitamins might result.

Use of Wheat Products. By-Products. The tendency at the

TABLE 10. COMPOSITION OF WHEAT PRODUCTS*

	Fiber, %	Protein, %	Fat, %	N-Free Extract, %
Ground wheat	2.6	13.2	1.9	69.9
Wheat bran	9.6	16.9	4.6	52.9
Wheat standard middlings	6.1	18.1	4.7	56.4
Wheat flour middlings	3.8	18.3	4.2	59.8
Red dog flour	2.6	18.2	3.6	61.9

* Feeds and Feeding, Morrison, 1950 (see Table 3).

present time is to use less of the wheat bran in poultry feeds and more of the middlings and red dog flour. There is considerable variation in the composition of the wheat products, depending upon the source and nature of the grain from which it is made. There is also considerable variation in appearance and texture, depending upon the process of milling and the closeness of milling. For example, a coarse standard winter wheat bran is quite different from a wheat bran obtained from a small local mill.

Wheat by-products have been demonstrated as being important ingredients in poultry rations. The results from tests in Northern Ireland[86] show the value of bran for egg production. Taylor and Lerner[87] concluded that the inclusion of 15 or 25 per cent of wheat bran in the ration resulted in more rapid growth, earlier sexual maturity, and lower egg weight at the beginning of laying. Mussehl, Ackerson, and Blish[88] report a good concentration of a feather-growth factor in wheat bran and state that as much as 40 per cent of bran can be used in chick rations with good results. Embleton[89] concluded that bran was a more economical base for mashes than alfalfa meal, when used to the extent of 20 per cent in the mash.

Bearse[90] reported that replacement, in the rations of laying hens, of as much as 50 per cent of the mash by standard mill run did not seriously interfere with egg-producing ability of the hens or mortality of the chicks. Poley[91] has also reported on the utilization of wheat and wheat by-products in the feeding of young chickens, particularly in respect to furnishing the various components of the vitamin B complex. Carrick and Roberts[92] reported that when 10 per cent each of wheat bran and wheat middlings replaced 20 per cent of ground yellow corn more feed was required per unit of gain, since the rate of growth was reduced and the feed consumption increased.

Hewitt[93] obtained satisfactory egg production in Australian

experiments when using various combinations of bran, pollards, ground wheat, oats, barley and maize, and brewer's grains.

Ground Wheat or Wheat Meal is frequently used in place of the wheat by-products. When fed, it should be coarsely ground. Experiments in England[94] indicate that wheat meal can replace up to 80 per cent of the maize meal of an all-mash ration, when the maize constitutes half the mash. The wheat rations produce light-colored yolks and legs. When using wheat meal in place of corn, the vitamin A content of the ration must be checked. Three to 5 per cent of good dehydrated alfalfa meal will prevent this deficiency condition. Twenty per cent of wheat meal has also been satisfactorily substituted for an equal amount of ground oats. South Dakota[95] reported that 30 per cent of ground red durum wheat gave equally satisfactory results, when used to replace 15 per cent each of bran and flour middlings in the mash part of a complete grain and mash ration for laying pullets.

Crushed Wheat has also been used with good results in poultry rations in place of wheat bran and wheat middlings. In experiments reported from Cornell University,[96] growth was greater, egg production was higher, and the body weight of the hen maintained better when crushed wheat replaced wheat bran and middlings. It was concluded that the greater efficiency was probably due to a greater amount of digestible nutrients being made available on the less fibrous rations.

LESS COMMONLY USED POULTRY FEEDS

ALGARROBA FEED consists of the fruit of the algarroba tree processed into a fine meal. It has a high sugar content, satisfactory protein, and high fiber. It is very aromatic and is sometimes used as an appetizer and tonic. Draper[97] suggested that algarroba bean meal could be used in Hawaii to supplement imported feeds for laying hens and for turkeys.

BAKERY REFUSE might consist of any kind of baked goods. Where the product is kiln dried, it can be used as an ingredient of the dry mash. It might also be used as a wet mash, by moistening with milk and feeding as "bread and milk." It might be used in place of part of the wheat products.

BEANS are not usually looked upon as a poultry feed. Cull beans, however, are sometimes fed. It is best to cook them and feed as part of a wet mash. Cull pink beans have been reported as being well utilized up to levels of 10 per cent. Bean meal[98] when included in rations for hens resulted in lower production and smaller eggs.

CHARCOAL. Because charcoal is an absorbent, especially of gases, it was included in poultry rations as an absorbent of gases and an intestinal corrective. Mangold and Damköhler[99] reported some benefit of charcoal in preventing diarrhea. Sipe[100] reported no effect upon egg production, health, or mortality of laying hens.

Experiments, conducted at Cornell,[101] showed that wood charcoal, when used in the feeding of chicks, did not have any effect on growth, mortality, body or shank pigmentation, or condition of feathering. When used in the feeding of laying hens, it did not have any effect on egg production, food consumption, food utilization, mortality, or yolk color. No detrimental results were noted, even when charcoal was incorporated in amounts equal to 8 per cent of the total ration. In most of the trials, the addition of charcoal increased food consumption, usually to the extent of the charcoal included. However, in mild diarrhea, produced by the feeding of dried whey, the condition of the droppings was benefited by charcoal feeding. In severe diarrhea, the consistency of the droppings was not influenced.

On the other hand, Almquist and Zander[102] reported that a chick diet, adequate for normal growth and health, was rendered, in effect, deficient in vitamins A, G, K, and the gizzard factor by the addition of an adsorbing charcoal. These findings point to the possibility of some measure of this effect in practical rations supplemented with charcoal, if the mash does not contain more than adequate levels of these factors, or if the mash consumption is reduced by heavy scratch grain feeding, or if the birds have unlimited access to charcoal. Hence the adsorbing power of charcoals in poultry rations is not necessarily a beneficial property.

Hunt[103] reports that riboflavin added directly to charcoal (Norite A) was 35 per cent available to chicks and that added to bone black it was 85 per cent available. Similar results were obtained in the case of pantothenic acid and niacin However, if the adsorbents were fed separately from the vitamin, somewhat more was available. In the case of riboflavin, the loss to the chicken was 15 per cent.

COCOA BEAN MEAL has been suggested as a poultry feed. It has been reported that chocolate meal is not eaten readily, is toxic, and at higher levels causes the chicks to lose weight Temperton and Shaw[104] report that the poisonous effects produced when cocoa wastes are fed are due to the presence of theobromine, the effects of which are cumulative. Fangauf and

Haensel[105] observed unsatisfactory results when 20 per cent of cocoa shell meal was included in the ration of Leghorn hens.

"COCOANUT OIL MEAL or COPRA OIL MEAL is the ground residue obtained after the extraction of part of the oil from the dried meat of the cocoanut. It must be designated and sold according to its protein content." This product contains a considerable amount of protein but is also high in fiber. Its feeding in one trial at the Maryland Station[33] did not give satisfactory results. This was due in part to the fact that it was unpalatable. Temperton and Dudley[106] conclude that, in the event of a shortage of bran, cocoanut cake meal can be used as a substitute, without detriment to the health or productivity of the birds. (See also Chap. 7.)

COWPEAS are not used in poultry rations, although small amounts could be fed in the same way as other leguminous seeds.[107]

ENZYME PRODUCTS have been suggested for the poultry ration, with the idea of furnishing enzymes to aid the digestion and assimilation of the food. Enzymes are found naturally in the digestive tract of the hen.

Improvement of the ration has been reported by the addition to the ration of protozyme,[108] a vegetable enzyme of fungus origin. Observations in regard to enzymes and their action[109] indicate that under normal conditions food utilization is as complete as possible, without the assistance of any enzymes from the outside. It is necessary, therefore, that many more detailed and controlled investigations be carried on with poultry before the use of artificial enzymes can be generally advocated. There is some evidence to indicate that fiber-splitting enzymes might enable the chicken to utilize some nutrients tied up or made unavailable by fiber.

MOLASSES, a by-product of the manufacture of cane sugar or beet sugar, contains a large amount of sugar. It is palatable and liked by farm animals. It is laxative and hence must not be fed in too large quantities.

"Feeding Cane Molasses is a by-product of the manufacture of cane sugar from cane and shall contain 48 per cent or more of total sugars expressed as invert sugar. Its solution in an equal weight of water shall test not less than 39.75 degrees Brix."

"Feeding Beet Molasses is a by-product of the manufacture of beet sugar from sugar beets and shall contain 48 per cent or more of total sugars expressed as invert sugar. Its solution in

an equal weight of water shall test not less than 39.75 degrees Brix."

"Feeding Corn Sugar Molasses is a by-product of the manufacture of corn sugar from corn and shall contain 43 per cent or more of reducing sugars expressed as dextrose, and shall contain 60 per cent or more of total carbohydrates (dextrins, and reducing and non-reducing sugars). Its solution in an equal weight of water shall test not less than 39.00 degrees Brix."

"Citrus Molasses is the partially dehydrated juice of citrus fruit. It shall contain not less than 45 per cent of total sugars expressed as invert sugar. Its solution in an equal weight of water shall test not less than 35.5 degrees Brix."

Satisfactory results with molasses have been reported from the Hawaii,[110] Louisiana,[111] Ohio,[112] and Cornell[113] stations. However, Maw[114] gives results from Canada which show that chicks increased food consumption without an increase in weight and that hens showed lower egg production. The Pennsylvania[115] Station also reported that performance was not significantly influenced by including up to 6 per cent of molasses in the rations of growing chickens or hens.

When molasses is used it replaces feeds rich in starch, such as corn. The amounts fed must be restricted as the droppings become very watery, owing in part to increased water consumption. This causes the litter to become damp and soiled. Flies are also attracted and collect in the pens of chickens fed heavily on molasses.

In the feeding of hens 5 to 7 per cent is usually recommended. For the feeding of broilers larger amounts have been used. When mixed with bagasse pith the Hawaii[110] Station has fed levels up to 35 per cent as a source of carbohydrates in layer rations.

Wood sugar molasses[116] prepared by the hydrolization of wood waste has also been satisfactorily substituted for cereal grains in rations for chicks and laying hens.

POTATOES. Small potatoes and potatoes when they are cheap can be used as a poultry feed. It must be remembered, however, that they are composed largely of water. Four to 5 pounds of potatoes are equivalent to 1 pound of grain. On the dry basis, they do not differ greatly from corn or wheat. Rations containing high proportions of cooked potatoes are likely to be deficient in protein, fiber, and the fat-soluble vitamins. The Ohio Experiment Station[117] suggests that potatoes should be cooked since raw potatoes are not satisfactory. The coefficients of digestibility[118] of raw potatoes are lower than those for cooked or

ensiled potatoes. After cooking the potatoes should be mashed and mixed with enough of the laying mash to make a crumbly mixture. This can be fed as a moist mash, feeding what the hens will eat in about 15 minutes. One hundred hens will thus consume 6 to 8 pounds of potatoes a day. They seem to like the mash better when it is warm.

Experiments reported from Canada,[119] the Irish Free State,[120] Michigan,[121] Norway,[122] and Wyoming[123] indicate that potatoes make a satisfactory substitute for corn or other feedstuffs rich in carbohydrates.

Results from England[124] show that potatoes were fed in large amounts to all kinds of stock since scarcity of grains and other imported concentrates, owing to war conditions, increased the feeding of home-grown feeds. Large amounts of potatoes (in some cases 50 per cent or more) were included in rations for laying chickens and ducks as well as rations for rearing pullets and ducklings. The feeding of potatoes to breeders and table poultry was not satisfactory.

Potatoes and various potato products have been used extensively in Germany.[125] This interest has been shown because the nutritive yield of potato acreage is greater than that of grain. Freshly steamed potatoes, up to 2½ ounces per day per bird, were given to laying hens. Potato flakes, up to 60 per cent of the food mixture, were fed to hens and chicks with satisfactory results when the ration was properly supplemented. However, high levels of ground, dried, raw potatoes are not recommended for baby chicks. For the fattening of poultry, ducks, geese, and turkeys, potatoes in every form may be made an essential part of the feeding as a supplement to and a substitute for grain fodder. Economic conditions must decide whether potato flakes or cereals are to be used.

The feeding of large amounts of steamed, ensiled potatoes to laying and breeding hens was satisfactory if an adequate amount of protein of high biological value was included in the ration. Similarly, potato-protein flakes, a by-product of starch production, could be used as supplementary protein feed when combined with animal protein feed.

Bolton and Hale[126] reported satisfactory results for egg production when dried potato slices or flakes were fed in amounts as high as 42 per cent of the ration. Results at the Maine[127, 131] Experiment Station indicated that dehydrated potatoes were not satisfactory as a substitute for corn in a chick ration, especially when 50 per cent or more of the corn was replaced. Substitution

up to 20 per cent did not affect feed efficiency. The California[128] Experiment Station reported a reduction in growth of both poults and chicks when they were fed sun-dried or oven-dried raw potatoes at a level of 20 per cent. Dried cooked potatoes, however, at that level appeared to be satisfactory. Experiments conducted at Cornell University[129] indicate that 20 per cent of potato meal can be used in place of corn meal or wheat standard middlings in rations for ducklings.

Dried potato solubles,[130] a by-product in starch production, was satisfactorily fed to chicks as a partial substitute for soybean meal. Potato starch pomace,[131] did not prove satisfactory in rations for chicks. The efficiency was very poor due probably to the high level of calcium.

SWEET POTATOES. Sweet potatoes and dehydrated sweet potato meal were used as feed in Louisiana.[132] The hens getting the cooked potatoes ate more than those receiving raw ones. The sweet potatoes were fed to replace green feed, and the egg production was entirely satisfactory. It was also found that sweet potato meal could be used as 20 to 25 per cent of the mash mixture and to replace carbohydrate feeds in chick rations. The Mississippi and Hawaii stations[133] reported poorer growth in chicks when dehydrated sweet potatoes were substituted for corn in the ration. The North Carolina Station[134] reported better gains for poults on a standard turkey starter mash than on the same mash when the principal vitamin A carriers were replaced by sweet potato flour. There was also a reduction in the vitality of those receiving the sweet potato flour in the ration The South Carolina Station[134] reported dehydrated sweet potatoes as a good source of vitamin A.

SHREDDED WHEAT WASTE can be fed to poultry when it can be obtained cheaply. It can be used in the same way as bakery refuse.

SUGAR may be used as a source of energy, but it is usually too expensive for regular feeding. Because it is primarily carbohydrate, no special advantage has been reported, even by adding it to a ration for finishing broilers.[135] The Hawaii Station[136] indicated that low grade sugar is a potentially good source of carbohydrates for mature chickens.

Sugar Beet Pulp. "Dried Beat Pulp is the dried residue from sugar beets which have been cleaned and freed from crowns, leaves, and sand, and which have been extracted in the process of manufacturing sugar " Ground sugar beets have been successfully adapted as a feed for hens in Germany,[137] but they are

not suitable in large quantities for chicks. The feeding of uncooked and steamed sugar beets to laying pullets in England[138] has given satisfactory results. A greater supplement of protein was required for sugar beets than for potatoes. Sugar beet slices are more efficient to use in feeding ruminants and should not be used for poultry except in times of scarcity of carbohydrate-containing food. The apparent digestibility of the dried beet pulp was extremely low.

"VELVET BEAN MEAL is ground velvet beans containing only an unavoidable trace of hulls or pods." It contains a large amount of protein. Special feeding values for poultry have not yet been determined.

YEAST. Dried yeast is the yeast of the botanical classifications Saccharomyces, Torulopsis, or Dandida, which has been separated from the medium in which it was propagated and dried. It shall contain not less than 40 per cent crude protein.

"Irradiated Yeast is yeast which has been subjected to ultraviolet rays in order to increase its antirachitic potency."

"Brewers' Dried Yeast is the dried, nonfermentive, nonextracted yeast resulting as a by-product from the brewing of beer and ale and shall contain not less than 40 per cent of crude protein on the moisture-free basis."

"Dried Torula Yeast is a yeast of the botanical classification Torulopsis which has been separated from the media in which [it was] propagated and dried. It shall contain not less than 40 per cent crude protein on the moisture-free basis."

"Grain Distillers' Dried Yeast is the properly dried yeast resulting from the fermentation of grains and yeast, separated from the mash, either before or after distillation."

"Molasses Distillers' Dried Yeast is the properly dried yeast resulting from the fermentation of molasses and yeast, separated from the medium, either before or after distillation."

Yeast, a rich source of the vitamin B complex, can be used in poultry rations for this purpose. Yeast can also be used to produce a fermented mash.

Adding yeast to a normal chick ration has shown no advantage in some experiments.[139] In some cases[140] the growth rate has been increased owing probably to an increase in some of the nutrients or to increased food consumption.

Some feeding experiments[141] with laying birds showed no apparent advantage in supplementing the regular laying ration with commercial yeast or diastase from the standpoint of egg production, egg size, body weight, mortality, or cost of feed per dozen

eggs. On the other hand, the feeding of yeast-fermented mash and live yeast at the North Carolina Station[142] resulted in higher egg production. The writers indicate that the feeding of yeast-fermented mash stimulated the appetite and led to higher feed consumption and to higher egg production. They also indicated that the enzymes of the live yeast were causative factors for higher production. Temperton and Dudley[143] reported fodder yeast as a satisfactory form for laying pullets.

UNUSUAL POULTRY FEEDS

Besides the more or less commonly used feedstuffs already discussed, a number of unusual products have been used or suggested for poultry rations, either because they were cheap or because the regular ingredients could not be readily obtained.

ACORNS. Temperton[144] concluded that it appeared safe to include ripe, ungerminated acorns up to 20 per cent of feed intake in rations for hens and ducks. When the amount of this type of acorn was increased to 40 per cent of the hens' ration, there was a decrease in egg production and the birds became constipated. No detrimental effect was observed in ducks when acorns made up to 50 per cent of the ration. The production of discolored yolks was attributed to germination of the acorns.

"BABASSU OIL MEAL is the ground residue obtained after the extraction of part of the oil from babassu kernels (*Orbignya speciosa*) by crushing, cooking or mechanical pressure. It must be designated and sold according to its protein content." Babassu meal has been reported by the California Experiment Station as giving satisfactory results when fed at levels up to and including 10 per cent.

BEET SEED.[145] When beet seed was substituted entirely for a grain ration of equal parts of wheat and barley, the hens ceased egg production, lost weight, and were in generally poor condition. However, in three groups of 25 hens each, beet seed successfully replaced 10 and 25 per cent of the grain mixture for 12 weeks, since egg production, egg size, feed consumption, and body weight were not significantly different.

CHEWINGS FESCUE SEED,[146] of such low germination as to be unsuitable for planting, may be used advantageously as a poultry feed. The composition resembles oats, 30 per cent of which was replaced by 30 per cent of the fescue seed

"DRIED CITRUS PULP, CITRUS MEAL, consists of the dried and ground peel, residue of the inside portions, and occasional cull

fruits of the citrus family with or without the extraction of part of the oil of the peel. If calcium oxide or calcium hydroxide is added as an acid in processing, the maximum percentage present, expressed as calcium (Ca), must be stated. If it bears a name descriptive of its kind or origin, it must correspond thereto.

"CITRUS SEED MEAL is a product principally of the seed of oranges and grapefruit singly or mixed, from which the major portion of the oil has been removed, and is composed mostly of kernel with such portion of the hull as is necessary in the manufacture of citrus seed oil. It may contain small amounts of the seed of other varieties of citrus. It must be designated and sold according to its protein content."

The Florida Experiment Station[147] has reported on the use of citrus meal. In general, citrus meal was not a satisfactory component of chick rations. Pullets 8 to 20 weeks old utilized citrus meal fairly well. Up to 15 per cent of citrus meal could be fed to laying pullets with no ill effects. Citrus seed meal proved unsatisfactory for chicks, but when extracted could be fed without apparent ill effects. The California Station reported that orange peel and pulp meal was eaten readily by chicks at levels up to 20 per cent of the ration, but the meal acted like an inert ingredient causing corresponding decreases in gain with increasing amounts of the orange peel and pulp meal.

DRIED COFFEE GROUNDS have been reported by Hammond[148] as being unsuitable for growing chickens. As little as 5 per cent was harmful. The deleterious effect could not be attributed to dilution of the diet.

GARBAGE. The shortage of feeds in England[149] due to the war resulted in the feeding of household garbage to poultry. This product, known as kitchen waste, consisted of unavoidable food waste from households. Vegetable peelings, principally potato, supplied about two-thirds of the fresh material. Reasonably good egg production was obtained when large amounts of the daily dry matter was provided as semi-dried processed food waste. The droppings of the birds eating swill were moister, but looseness was not so pronounced as to cause scouring or to affect the health of the birds. The swill rations were improved by supplementary protein or access to grass runs. The weights of the groups of growing pullets (8 to 21 weeks old) that ate the swill were reasonably satisfactory. Semi-dried town food waste has beed fed with satisfactory results to female ducklings from the age of 2 weeks to the laying stage.

The Hawaii Agricultural Experiment Station[97, 150] reported that raw garbage and processed garbage meal could be used in poultry rations. Satisfactory and economical growth could be obtained by feeding ducks on raw garbage, when properly supplemented with a limited amount of commercial poultry mash or vitamin and mineral concentrates. The feeding of raw garbage necessitates spending considerable time in maintaining satisfactory sanitary conditions about the poultry house. It is essential to clean the feed troughs each day to prevent undesirable odors and attraction of flies.

HEMPSEED MEAL has been reported as efficiently replacing cereal grains up to 20 per cent of the ration.

MANURE. Hammond[151] reported that cow manure had a marked beneficial effect on the growth of chicks if it was added to a diet deficient in riboflavin. It had no deleterious effect on the growth of chicks if it was added to a completely balanced diet. Dried cow manure served as a partial substitute for alfalfa leaf meal. As an ingredient in turkey diets fresh cow manure, dried at 80° and 120° C., was found to be a satisfactory substitute for 10 per cent of alfalfa leaf meal in a diet adequate in vitamin A and nearly adequate in riboflavin. Dried sheep manure[152] has also been reported as a possibility in poultry rations.

"PALM KERNEL OIL MEAL is the ground residue from the extraction of part of the oil by pressure or solvents from the kernel of the fruit of *Elaeis guineensis* or *Elaeis melanococco*." Palm kernel meal, which is not unlike bran in protein and fiber but much less bulky, was reported by Temperton and Dudley[153] as being satisfactory up to levels of 20 per cent as substitutes for concentrated starchy foods.

PERILLA MEAL has been reported by the California Station as being a palatable feed, relatively high in digestible protein and total digestible nutrients.

RUMEN CONTENT. Preliminary experiments reported from Italy[154] on the nutritive value of the contents of the rumen of slaughtered animals, when fed to growing chickens, indicated an increase in growth, when they were added to a diet complete except for a possible deficiency of proteins. Hammond[151] also reported dried rumen contents as a partial substitute for alfalfa leaf meal in rations for chicks.

STRAW EXTRACT. Experiments reported from England[155] show unfavorable results from feeding a caustic soda extract of straw to pullets and ducks. The highest level that could be used

without excessive scouring was 6 per cent, but this amount significantly lowered egg production.

SWEET LUPIN SEEDS. The seeds have a high content of crude protein, crude fat, and nitrogen-free extract. Experiments reported from Germany[156] indicate high digestibility of the seeds. In rearing poultry it was found that two-thirds of the animal protein usually used could be replaced by sweet lupins.

TAPIOCA MEAL has a high starch content. Experiments reported from England[157] show that, as a wartime substitute for the more usual kind of poultry food, tapioca meal at a level of 20 per cent proved suitable for the rearing of cockerels and pullets and even at higher levels of 40 and 50 per cent produced no discernible harmful effects but was less satisfactory.

"DRIED TOMATO POMACE is a mixture of tomato skins, pulp, and crushed seeds resulting from the process of extracting the juice from tomatoes." On the basis of its vitamin A, B_1, and B_2 content, Esselen and Fellers[158] suggest that dried tomato pomace should be considered as a desirable feed. It is palatable when fed at 10 to 15 per cent levels.

WOOD SUGAR. Feeding experiments with wood sugar, reported from Germany,[159] indicate that as much as 30 per cent can be included in poultry mashes.

OTHER FEEDS. Many feeds have been used locally in regions where they are produced. For example, the Hawaii Station[160] reports that avocados, bananas, sweet potatoes, and taro waste were found to make economical supplemental feeds. Poi could be used but produced more expensive gains when fed to broilers. In the Philippines[161] palay, tahup, and cassava refuse meal have also been fed to poultry. Other feeds[162] used in poultry rations are adlay cereal, manioc meal, dried penicillin mycelium, algae, and raisins.

Many feeds have been suggested as ingredients of poultry rations which have not proven satisfactory. Besides cocoa bean meal, dried coffee grounds, and straw extract which have been previously mentioned, other feeds[163] which have been shown unsatisfactory are green banana meal, ground carob pod and bean, horse chestnuts and elderberries, dried sewage sludge, and hairy vetch seed.

There are many products that are used occasionally, and undoubtedly other by-products that could be used will appear Unless there is a shortage of feeds, or unless such products can be obtained at a very low price, have been tried out, and can be

obtained in sufficient amounts, it is probably best not to use them. There are normally available a choice of satisfactory feeds that are known and can be obtained in sufficient quantities and at a reasonable price. It is, therefore, usually best to make up a poultry ration of those feeds, the feeding values of which have been demonstrated, unless one is willing to take a chance on the unknown.

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CHAPTER 6

POULTRY FEEDS—
ANIMAL PROTEIN SUPPLEMENTS

Poultry rations are composed largely of cereals and cereal by-products. It is necessary to include some protein concentrates in order to satisfy the protein requirements. A wide variety of ingredients will serve this purpose.

MEAT PRODUCTS

"MEAT is the clean, wholesome flesh derived from slaughtered mammals and is limited to that part of the striate muscle which is skeletal or that which is found in the tongue, in the diaphragm, in the heart, or in the esophagus and does not include that found in the lips, in the snout, or in the ears; with or without the accompanying and overlying fat and the portions of skin, sinew, nerve, and blood vessels which normally accompany the flesh. If it bears a name descriptive of its kind it must correspond thereto.

"The term 'meat' when applied to the corresponding portions of animals other than cattle, swine, sheep, and goats shall be used in qualified form, as, for example, 'horse meat,' 'reindeer meat,' 'whale meat,' etc."

Meat has been used largely in the diet because it possesses many desirable characteristics. It is very palatable, is easily digested, and also has a high nutritive value. It is rich in protein and in such minerals as phosphorus and iron.

Meat scraps and tankage[1] are prepared from the inedible portion of slaughtered animals and from entire carcasses of diseased and dead animals. The material is rendered to extract the fat, and the residues are used for feed or fertilizer. The raw materials may be obtained from (1) slaughter houses, in which case it consists usually of cavity contents, trimmings, and cracklings, (2) dead animal rendering plants, (3) city fat smelters, and (4) hotel and restaurant waste rendering plants.

"MEAT MEAL OR MEAT SCRAP is the finely ground, dry-rendered residue from animal tissues exclusive of hair, hoof,

horn, blood, manure, and stomach contents, except in such traces as might occur unavoidably in good factory practice. When these products contain more than 4.4 per cent of phosphorus (P), they shall be designated either 'Meat and Bone Meal' or 'Meat and Bone Scrap.' If the product bears a name descriptive of its kind, composition, or origin it must correspond thereto. It must be designated and sold according to its protein content."

Meat scraps consist only of dry-rendered tissues and contain no blood or "stick." In the dry-rendering process the materials are heated in steam-jacketed tanks. No water is added directly to the materials. The fat is removed, and the remaining cake or cracklings is ground to make the meat scraps. Meat scraps are high in protein, usually having about 45 to 60 per cent. Occasionally a product contains less than 45 per cent, especially when the bone content is unusually high. On the other hand, some meat scraps contain as much as 75 or 80 per cent protein. Ordinarily, the fat content is relatively low, and it should be practically free of fiber.

The nutritive value of these products[2] varies considerably, depending upon the kind of material from which they are made and the conditions of manufacture. For example, the organs of the body have higher feeding value than the other tissues. Meat products are also likely to contain varying amounts of connective tissue, made up largely of collagen or gelatin which is deficient in such amino acids as tyrosine, cystine, and tryptophan Meat scraps or meat meal from various manufacturers may not give the same rate of growth, even when fed at the same protein level.

The biological value[3] of the nitrogen of pork tenderloin has been reported to be 79, whereas that of pork cracklings, consisting largely of connective tissue, was found to be 25. The biological value of the proteins of meat meals containing no bone was found to be much higher than that of those containing a large proportion of bone.[4]

Wilgus, Norris, and Heuser in tests at Cornell[5] showed that meat scraps were variable in protein efficiency, owing probably to differences in raw materials. There seemed to be a distinct difference in favor of the 55 per cent product as compared with the 50 to 45 per cent products. The rendering process apparently causes little variation in the protein efficiency There is also considerable variation in the riboflavin content of different samples of meat scraps, depending upon ingredients used and conditions of manufacture.

A high free fatty acid content of meat scraps[6] is not necessarily a true factor for the evaluation of the product, but generally is not desirable. Meat scraps high in free fatty acids have been shown[7] markedly to increase the death rate, to decrease the rate of growth and feed consumption, and to retard calcification. The evidence presented indicates that the inferior results are probably not so much attributable to the free fatty acids, per se, but to an inactivation of vitamin A and, to a lesser degree, of other fat-soluble vitamins, presumably owing to oxidation. The formation of free fatty acids is accelerated by increased temperature, especially when it is accompanied by an increase in the moisture content. It would appear that the acidity of the fat is increased through the presence of fat-splitting enzymes, most active around temperatures of 80° to 90° F. Although a low free acidity of the fat gives no assurance that a meat scrap is desirable in every respect, a high acidity at once indicates an inferior product. To that extent the free fatty acids of meat scraps can be used as a criterion for the quality of the product.

Meat scraps as compared with fish meal are likely to be lower in available lysine, methionine, cystine, and tryptophan.[8]

"DIGESTER TANKAGE, MEAT MEAL TANKAGE, OR FEEDING TANKAGE is the finely ground, dried residue from animal tissues exclusive of hair, hoof, horn, manure, and stomach contents, except in such traces as might occur unavoidably in good factory practise, especially prepared for feeding purposes by tanking under live steam or by dry-rendering or a mixture of the products. When these products contain more than 4.4 per cent of phosphorus (P), they must be designated 'Digester Tankage with Bone,' 'Meat and Bone Meal Digester Tankage,' 'Meat and Bone Meal Tankage,' or 'Feeding Tankage with Bone.' If the product bears a name descriptive of its kind, composition, or origin, it must correspond thereto."

Tankage is similar to meat scraps in that it is also made from the residue of animal tissues. However, it is usually prepared under the wet process known as tanking. The raw material is cooked under live steam; the grease is removed; and the product is dried at a very high temperature and ground to a granular meal. The liquid is evaporated down and is known as "stick." The residue contains about 45 per cent protein and usually has added to it "stick" and blood to raise the protein to about 60 per cent. Tankages are usually the product of the wet process, although they may be that of the dry process to which blood and stick have been added. Tankages ordinarily are very dark colored.

They are also likely to contain more of the fiber because of inclusion of the contents of the digestive tract. As far as protein is concerned, they usually run around 60 per cent, which is somewhat higher than meat scraps.

The tankages are not so palatable as the meat scraps and have generally not given such good results for growth,[9] although very favorable results have been reported for mature birds. The results obtained depend largely upon quality and palatability. The deficiency has been reported as being probably tryptophan.

The question still remains whether meat meal should contain the "stick." Tests at the Institute for Animal Physiology at the Agricultural High School at Berlin[10] indicated that the presence of "stick" or "extract" in animal meal has an irritating effect on the digestive organs of animals. The United States Department of Agriculture[11] reported that liquid stick and a mixture of blood meal and stick in the diet seemed to cause an increased embryonic mortality throughout the incubation period.

There is undoubtedly greater variation in tankages than in meat scraps, ranging all the way from those that are prepared specially for feeding purposes to those that are not fit for feeding purposes and are intended only for fertilizer.

"MEAT BY-PRODUCTS consist of any nonrendered, clean, wholesome part of the carcass of slaughtered mammals other than meat, such as lungs, spleens, kidneys, brains, stomach and intestines free from their contents; it does not include skin, horns teeth, hoofs, and bones. If it bears a name descriptive of its kind it must correspond thereto.

"The term 'meat by-products' when applied to the corresponding portions of animals other than cattle, swine, sheep, and goats shall be used in qualified form, as, for example, 'horse meat by-products,' 'reindeer meat by-products,' 'crab meat by-products,' etc."

Experiments reported from England[12] showed that hide-fleshings, a by-product of tanneries, contained 66.25 per cent protein and was digested by poultry in the same way as meat-meal protein. Dried muskrat meal[13] was shown to be satisfactory in chick rations.

FRESH MEAT. There is the possibility of fresh meat as a source of animal protein, using meat trimmings or often the carcasses of cows or horses This is a source that is not very extensive but can be used. In using such meat, ordinarily the best practice is to cook the carcass, grind it, and then feed in with a wet mash.

Jack rabbits have been suggested as a source of fresh meat in New Mexico.[14] The meat was fed by hanging the cleaned carcasses in the yards, where the birds could pick the meat from the bones. Egg production was satisfactory when the laying flock was fed only grain and raw rabbit meat.

LIVER MEALS

"ANIMAL LIVER MEAL is the product obtained by drying and grinding liver from slaughtered mammals. This product must contain at least 27 milligrams of riboflavin per pound."

"ANIMAL LIVER AND GLANDULAR MEAL is the product obtained by drying and grinding liver and other glandular tissue from slaughtered mammals. At least 50 per cent of the dry weight of the product must be derived from liver, and the product must contain at least 18 milligrams of riboflavin per pound."

"EXTRACTED ANIMAL LIVER MEAL is the product obtained by drying and grinding the residue of animal liver tissue from which a large portion of the vitamins and/or minerals have been removed."

MILK PRODUCTS

Milk is valuable for poultry because of its vitamins, lactose, minerals, and proteins.

Skimmilk or buttermilk in any form provides riboflavin and associated factors which are very important, especially for growing chicks.

About one-half the dry matter of skimmilk or buttermilk is composed of lactose or milk sugar. Milk begins to "sour" when certain acid-producing bacteria start a fermentation of the lactose and change a small part of it to lactic acid. Lactose favors the development of acid-producing bacteria in the intestines, and through the multiplication of these "friendly germs" the objectionable putrifactive bacteria are suppressed, thus providing good intestinal hygiene. In tests reported from Ohio[15] the *p*H of the contents of the duodenum and ileum was shown to be increased, while the *p*H of the cecal contents was markedly decreased by the use of milk. The cecal contents present a characteristic firm, brownish, pultaceous mass when birds are fed upon milk-free rations. This invariably changes to a yellow, creamy, frothy mass when birds are fed upon rations containing milk products. Lactose also seems to function in some way in

the assimilation of minerals, especially of calcium and phosphorus. It has been suggested,[16] however, that the use of products rich in lactose be restricted, since in the hen glycogen is either not produced from lactose or is produced only in minimal amounts, more than 1/2 of the lactose being excreted unchanged.

Part of the beneficial action of milk may be due to the improvement of the mineral intake, especially sodium, chlorine, and calcium, in which grains are deficient.

Milk proteins, composed chiefly of casein, lactalbumin, and lactoglobulin, are of excellent quality and easily digested. They function efficiently in supplying the body needs.

Milk in any form adds palatability to a ration and therefore tends to increase the feed consumption, which in turn is likely to increase growth and egg production.

MILK FOR CHICKS. Milk as a part of the chick ration has resulted in many benefits. The early experiments on the feeding of chicks have dealt almost entirely with a comparison of milk and meat scrap as sources of animal protein. A study of 36 early trials reported from various experiment stations[17] showed all in favor of milk. The maximum benefit from milk is obtained during the first 2 months of the chick's life.[18]

The Connecticut Station[19] reported that milk feeding stimulated growth and caused a reduction in deaths from general causes, that the chicks were larger, stronger, and more vigorous, and that there was a reduction in the death rate from bacillary white diarrhea. The Indiana Station[20] reported that milk feeding made the chicks less susceptible to disease and hence lowered mortality, particularly where the chicks were raised in confinement.

A special value of milk, previously important, was its effect upon coccidiosis.[21] This disease is caused by a protozoan parasite which develops and multiplies in the cells of the walls of the intestines, thereby injuring the cells The beneficial results seemed to be due to the lactose Coccidiosis is now more economically and effectively controlled by the use of medicants such as sulfaquinoxaline.

The benefits of milk feeding to chicks were due particularly to its vitamin value. Probably the riboflavin is the most important vitamin. The North Carolina Station[22] indicated heavier mortality in a meat-fed lot, as compared to a milk-fed group, in which the losses were due to vitamin A deficiency.

In general, milk fed to chicks has proved to be beneficial when compared with rations containing no milk.[23] However, satisfac-

tory substitutes for dried skimmilk in chick rations have been made by supplying the nutrients furnished in milk. Hammond and Titus[24] used different mixtures of alfalfa leaf meal, dried whey, B-Y feed, fish meal, meat scrap, and peanut meal as substitutes for dried skimmilk. Nikolaiczuk and Maw[25] found that a combination of dried brewers' yeast and fish meal satisfactorily replaced dried skimmilk.

MILK FOR HENS. Milk, including the liquid, condensed, and dried forms, has proved to be a very effective protein feed as far as egg production is concerned. Comparing milk with the meat products, we find that most of the experiments favor the birds receiving milk.

Several stations[26] have reported favorable results on a mashless ration, in which only grain was fed, with an abundant supply of either the liquid milk or semi-solid buttermilk.

The Washington Station[27] reported improved hatchability when powdered whey, condensed buttermilk, and condensed buttermilk containing cereal grasses were fed as supplements to a breeding hen ration. Balance studies[28] to determine the biological values of the proteins in feeds showed that the value of a basal mash plus milk was significantly higher than that of earthnut mash and soy mash.

Milk is also reported as producing larger eggs than meat (see Chap. 9).

LIQUID MILK may be used where it is available on the farm or can be readily obtained near by. It is usually given as a drink. When feeding pullets or laying hens, buttermilk or skimmilk may be used in place of meat scraps, 12 to 14 quarts being allowed for 100 hens each day. It is more economical, however, to keep some protein concentrate in the mash.

In considering the amount of milk to feed, the Kentucky Station reports that 1 gallon of milk had the same value as 1 pound of meat scrap. The Indiana Station[29] reports that Leghorn pullets consumed 93 pounds of skimmilk per year.

Extensive trials conducted in Germany[30] and experiments reported from Norway[31] have shown the value of feeding skimmilk to laying hens.

No different results have been obtained when feeding chickens on sweet milk, naturally soured milk, artificially soured milk, or milk to which lactic acid was added. Sour milk is probably preferable since it is difficult to keep milk sweet when it is exposed to high temperature, and because the acid taste seems to make it more appetizing. The Idaho Station[32] reports sweet

skimmilk as having a tendency to cause digestive disorders.

It is more difficult to maintain sanitary conditions when liquid milk is fed. During the summer months, flies are likely to be present around the milk vessels in large numbers. Flies are one of the intermediate hosts of tapeworms. The Kansas Station[33] reported that 91.1 per cent of the hens fed liquid milk were infested with tapeworms as compared with 51.3 per cent of those receiving no liquid milk. The infested birds also showed a higher degree of infestation. The reverse was true for round and ceca worms.

"EVAPORATED BUTTERMILK, CONCENTRATED BUTTERMILK, or CONDENSED BUTTERMILK is the product resulting from the removal of a considerable portion of water from clean, sound buttermilk derived from natural cream to which no foreign substances have been added excepting such as are permitted and necessary in the manufacture of butter. It shall contain not less than .055 per cent of butterfat for each per cent of solids, and not more than .14 per cent of ash for each per cent of solids."

"CONDENSED SKIMMED MILK is the product resulting from the removal of a considerable portion of water from clean, sound skimmed milk. It shall contain not less than 27 per cent of total solids."

"EVAPORATED CULTURED SKIMMED MILK, CONCENTRATED CULTURED SKIMMED MILK, or CONDENSED CULTURED SKIMMED MILK is the product resulting from the removal of a considerable portion of water from clean, sound skimmed milk which has been cultured by a suitable culture of lactic bacteria. It shall contain not less than 27 per cent of total solids."

Condensed buttermilk or skimmilk has been used to advantage as a supplement to the regular mash and grain at the rate of 2 pounds a day for 100 hens. It is often fed in paste form, as it comes from the container. In the summer time, or whenever a wet mash is fed, the milk in condensed form may be diluted with a little water and used to moisten the mash

"DRIED BUTTERMILK is the product resulting from the removal of water from clean, sound buttermilk derived from natural cream to which no foreign substances have been added, excepting such as are necessary and permitted in the manufacture of butter. It shall contain not more than 8 per cent of moisture, not more than 13 per cent of mineral matter (ash), and not less than 5 per cent of butterfat, as determined by the Roese-Gottlieb method."

"DRIED SKIMMED MILK is the product resulting from the removal of water from clean, sound skimmed milk. It shall contain not more than 8 per cent of moisture."

The Pennsylvania Experiment Station[34] reported that the most efficient gains in body weight, on the basis of dried skimmilk intake, were made by the chicks receiving the 1.25 and the 2.5 per cent levels. From the standpoint of egg production, egg weight, and hatchability, the most efficient performance by laying pullets occurred at the 2.5 and 5 per cent levels. Results at the 2.5 and 3.75 per cent levels were essentially as satisfactory as the higher levels.

"DRIED CULTURED SKIMMED MILK is the product resulting from the removal of water from clean, sound skimmed milk which has been cultured by a suitable culture of lactic bacteria. It shall contain not more than 8 per cent of moisture."

WHEY in liquid form is not much used in poultry rations. It contains little protein. The dry matter of whey is mostly milk sugar. It can be used, when available in the natural state, for moistening mashes or it can be given to the birds as a drink. Results at the Idaho Station[35] show a production of 106 eggs for whey, as against 89 for no animal protein and 146 for the pen receiving skimmilk. It is probable that the vitamin content could be more fully utilized if some compensation were made for the protein.

"DRIED WHOLE WHEY is dried, clean, sound cheese and/or casein whey. It shall contain not less than 65 per cent of lactose." Because of its high milk sugar content, dried whey or milk sugar feed was of special value in rations for the control of coccidiosis. It is an important source of riboflavin and other water-soluble vitamins. It has also been suggested that it contains an unidentified growth factor. Because of its laxative nature the amounts fed must be restricted, 10 per cent being the maximum amount recommended.[36]

"CONDENSED WHOLE WHEY is the product resulting from the removal of a considerable portion of water from clean, sound cheese or casein whey, either or both. It shall contain not less than 62 per cent of total whey solids. When this product contains less than 62 per cent of total whey solids, it shall be designated 'condensed whey, . . . per cent solids.'"

"CONDENSED WHEY SOLUBLES is the product resulting from the removal of albumen and the partial removal of milk sugar from clean, sound whey, to which no foreign substances have been added except such as are necessary in the manufacture of milk sugar."

"DRIED WHEY SOLUBLES is the product resulting from the removal of albumen and the partial removal of milk sugar from clean, sound whey, to which no foreign substances have been added except such as are necessary in the manufacture of milk sugar."

"DRIED MILK ALBUMIN is the dried coagulated protein fraction separated from whey. It shall contain not less than 75 per cent protein (N × 6.25) on a moisture-free basis." Milk albumin results as a by-product in the manufacture of milk sugar. It contains most of the casein and albumin of the milk. It usually contains about 45 per cent protein and 25 to 30 per cent ash, although some products have a much higher percentage of protein. It has been used with favorable results as a source of protein in poultry rations.[37]

"CASEIN (FEEDING) is the product resulting from acid or rennet precipitation of skimmed milk. It must contain at least 80 per cent of crude protein." Its cost limits its use to experimental rations. With a lower relative cost it could be used in poultry rations as a source of protein.[38]

COTTAGE CHEESE is not used to any extent in poultry feeding. It is a valuable feed, however, and can be used. The Arizona Experiment Station[39] reported on a method for preserving skimmilk curd on the farm by adding formalin. Curds, conserved in this way, can be fed to hens and chickens without any danger.

CHEESE MEAL[40] has been reported as giving good results in poultry rations.

Milk can be used in different forms about equally satisfactorily.[41] The forms to use will depend upon convenience of obtaining them, the feeding system, and the cost. The price one can afford to pay for the different forms of milk depends to a large extent on the total solids each contains and the percentage of protein.

Form	Per Cent Solids	Per Cent Protein
Liquid milk	7 to 9	3 6
Condensed milk	28 to 30	12 0
Dried milk	90 to 95	35.0

Any of the various forms of milk can be fed to young stock.[42] Results reported from Nebraska favored dried buttermilk as compared with dried skimmilk. The liquid milk was reported to give better results than the dried product in trials conducted in Scotland and Wisconsin. Card reports no significant difference between liquid, condensed, and dried milk. In feeding chicks at

Cornell, it was found that there was little difference in growth due to the form of milk that was used. The Connecticut Station reports sweet and sour milk of about equal value, with probably a slight preference for the sour milk.

In the comparison of the different forms of milk for hens, there was generally no difference in the results. However, the Washington Station[43] reported liquid skimmilk superior to milk powder and other forms of protein.

MARINE PRODUCTS

In this category the fish meals are the most important. Fish meal was formerly utilized only as fertilizer, but, with improved methods of handling, better products are available.

"FISH MEAL is clean, dried, ground tissues of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil. If it contains more than 3 per cent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 per cent."

"FISH RESIDUE MEAL is the clean, dried, undecomposed residue from the manufacture of glue from non-oily fish. If it contains more than 3 per cent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 per cent."

The product obtained from fish or fish waste which is suitable for animal consumption is usually called fish meal.[44] The products which are fit only for fertilizer are called fish scrap or fish guano.

CLASSES OF FISH MEAL. Two general classes of fish meal are produced in the United States:

1. White Fish Meal, which is low in fat and hence called lean fish meal, made principally from the cod, halibut, hake or ling, whiting, haddock, plaice, sword, and tuna, utilizing only the non-edible portions of edible fish, such as heads, backs, and fins, or whole unusable or unsalable fish.

2. Dark Fish Meal, which is made from fish rich in oil, such as the herring, menhaden, sardine, pilchard, and mackerel (in which case the whole fish is generally used), and from the wastes from the shrimp- and salmon-canning industry. Oily fish are usually treated to recover a greater or lesser portion of the oil and the residue dried and ground.

COMPOSITION OF FISH MEALS. Fish meal is a feed that

contains a large amount of protein and also a large proportion of ash or bone-forming material. It contains a relatively large amount of iodine. A good fish meal will show approximately the following composition:

	Per Cent
Protein	55-60
Phosphate of lime	18-25
Other minerals	3-5
Oil	2-5
Moisture	10-14

There is considerable variation in composition, mechanical condition, and other physical characteristics, depending upon source of the raw material and the process of manufacture. Meals are produced both by the vacuum and by direct heat processes.

Vacuum-dried cod and vacuum-dried haddock meal have been reported rich in vitamin A, whereas flame-dried and steam-dried menhaden meals supply little if any of this vitamin.[45] Growth experiments showed the protein in the vacuum-dried cod and the vacuum-dried haddock meal to be superior in quality to that of the flame-dried menhaden, while the steam-dried menhaden meal appeared to occupy an intermediate place. There were also indications that the vacuum-dried product was superior in one or more of the substances in the vitamin B complex. The proteins of vacuum-dried meal and steam-dried meal have been reported superior in both digestibility and biological value to those of flame-dried menhaden meal.

Maine[46] white fish, herring, and sardine meal were found to contain vitamin D. The rapid fire-dried sardine meal contained this vitamin at a protective level when fresh. The sample containing the highest percentage of fat was the most potent in vitamin D. The fish proteins, fed as 10 to 12 per cent of the ration by weight, supplied protection against vitamin D and riboflavin deficiencies for the period of 3 to 11 weeks of age.

The relative protein efficiencies of various fish meals (with casein rated as 100) determined at Cornell[5] are: vacuum-dried and steam-dried white fish meals, 104; domestic sardine meal, 98; flame-dried white fish meal, 94; steam-dried menhaden fish meal and Asiatic sardine meal, 91; flame-dried menhaden fish meal, 80. The relative riboflavin content of these meals (with dried skimmilk rated as 19) are: vacuum-dried white fish meal, 10; domestic sardine meal, 9; steam-dried and flame-dried

white and menhaden fish meals and Asiatic sardine meal, 5. The Texas Station[17] also reported that vacuum-dried fish meal gave the best results of any of the protein feeds studied, when used as a supplement to any two other protein feeds.

Also in a study to determine the effect of the manufacturing process upon nutritive values, it was shown at Cornell[48] that dry-rendered haddock meals possessed a greater protein value and 50 per cent more riboflavin than those wet-rendered by similar processes of drying. A flame-dried meal was of inferior value. The use of vacuum drying with steam drying materially preserved the riboflavin content but did not improve the relative protein efficiency over that obtained without the use of vacuum. Overheating[49] fish meal during drying depresses the availability of the amino acids.

In comparing salmon fish meals, a Columbia River salmon fish meal, with a high fat content, and secured late in the fall, was distinctly inferior in quality to the other meals.[50]

HERRING MEAL is not so desirable as some others for poultry feeding. It is darker in color, contains more oil, and varies considerably in quality and composition. The two variables are salt and oil, large amounts of either being undesirable.

USE OF FISH MEALS. Fish meals may not be so palatable as some other animal protein concentrates. There is risk of taint to the flesh and product when large quantities are used, especially those with a high oil content. However, they have given good results when used in chick rations.[51]

"CRAB MEAL is the undecomposed ground dried waste of the crab and contains the shell, viscera, and part or all of the flesh. It shall contain not less than 25 per cent of protein. If it contains more than 3 per cent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 per cent."

Average samples of crab meal run about 28 per cent protein. The calcium carbonate content is high, running over 40 per cent. In feeding trials, it has been shown to compare favorably with meat meal and fish meal.[52] Hairy crabs[53] have been reported as not being satisfactory as an albuminous food, owing probably to the high ash content (about 40 per cent).

"SHRIMP MEAL is the undecomposed ground dried waste of the shrimp and contains the head, hull, or the whole shrimp, either or in mixture. If it contains more than 3 per cent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 per cent."

Shrimps are a valuable food compared with meat meal.[53] The feeding value of sun-dried shrimp meal for poultry is considerably less than steam-dried (or other unsalted) shrimp meal.[54] The protein content of shrimp meal runs close to 50 per cent, which makes it a valuable concentrate.[55] Shrimps are also rich in iodine. Chicks fed shrimp "bran," to the extent of 10 per cent of a ration, did not grow quite so well as chicks fed fish meals or meat meal.[56]

LOBSTER MEAL is less valuable tham shrimp meal but may be a useful food for poultry.[53]

STARFISH MEAL, prepared from the starfish (*Asterias forbesi*), contains about 28 per cent protein and 60 per cent ash. When the calcium and phosphorus are adjusted, it compares favorably[57] with fish meal and meat scraps in feed efficiency and in the production of shank pigment. The high mineral content limits the quantity that can be used in a chick ration to about 5 per cent. Compared with fish meal, starfish meal contains as much riboflavin but probably less of the nutritional factors that prevent poor feathering and dermatosis of the feet.

DOGFISH MEAL, prepared by dry-rendering methods, was reported by the Washington Station[58] as having little value as a protein feed. On the other hand, wet process meal, prepared with good care and speed, had gross protein values comparable with pilchard fish meal and soybean meal.

WHALE MEAL is prepared from the clean, dried undecomposed flesh of the whale, after part of the oil has been extracted. If it contains more than 3 per cent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 per cent.

Whale meal of good quality (free from bone and of very low fat content) has been reported to possess good feeding value for poultry.[59]

SHARK MEAL has been reported[60] to increase the egg yield greatly when 10 per cent of this product is added to a cereal ration. It has also given good results as a supplement in chick rations.

COD LIVER MEAL is the ground residue of cod livers after the oil has been extracted. It contains about 50 per cent protein and is ordinarily not used on account of its protein, but it is a possible source of this nutrient. It also contains a large amount of fat, which gives it its antirachitic value. The protein from cod liver meal has been reported to be lower in value than the protein of buttermilk, fish meal, and meat scrap.[61]

"FISH LIVER AND GLANDULAR MEAL is the product obtained by drying the complete coelomic contents of the fish. At least 50 per cent of the dry weight of the product must be derived from fish liver and the product must contain at least 18 milligrams of riboflavin per pound."

"CONDENSED FISH SOLUBLES is the product obtained by condensing the water resulting from the hydraulic extraction of oil from fish."

Favorable results[62] have been reported in the use of condensed fish solubles and other fish water products in chick and poult rations, especially those composed largely of corn and soybean oil meal. The supplementary value of these products was due largely to water-soluble factors, rather than the protein content. Condensed fish solubles contain an unidentified factor not present in vegetable proteins.

CONDENSED WHALE SOLUBLES[63] have also been shown to be of value as a supplement in poultry rations.

"HOMOGENIZED CONDENSED FISH is a partially dehydrated, homogeneous product made from fish and/or fish cuttings, from which a part of the oil may have been removed. It shall contain not less than 50 per cent of total solids."

SHELLFISH MEAL is a product made from blue mussels. It has been reported to give favorable results in poultry rations in Denmark. The protein content is only 11 to 12 per cent.

SEAWEED MEAL containing about 7 per cent protein has been reported as an excellent food for hens in Norway. However, it has considerable fiber and probably cannot be fed in large amounts.

KELP MEAL. Most of the kelp or seaweed meal is manufactured from the giant brown kelp of the Pacific Coast The kelp is harvested by an especially adapted type of mowing machine This wet kelp is then dried and ground into meal, which, in appearance, resembles alfalfa meal. Its principal value is as a mineral supplement. When fed to layers at a level of 10 per cent it produced damp droppings.[64] Chicks tolerated up to 10 per cent.

BLOOD PRODUCTS

There is probably nothing that the hen likes better than fresh blood. This great liking for fresh blood often results in severe losses due to various forms of cannibalism

FRESH BLOOD has been fed to ducks, pullets, and hens [65] The fresh blood used by the Western Washington Experiment Station was a regular slaughter house product, sold commercially under

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the term "blood sausage" blood. It was an edible blood produced under government inspection, was practically free of bacteria, and had all the fibrin removed so that it would not coagulate.

"BLOOD MEAL is ground, dried blood."

"BLOOD FLOUR is dried blood, prepared by special processes and reduced to a fine powder."

The dried blood is very high in protein (approximately 70 per cent) but as the only source of protein does not give good results.[66] This failure is probably due to unpalatability, decrease in digestibility attributable to the manufacturing process, and low biological value of its protein. Grau and Almquist[67] reported that the serum and fibrin fractions of beef blood are of much better quality than the blood cell fractions. However, the blood cell fraction will support chick growth when supplemented with isoleucine. Mixtures of blood cells and corn gluten meal gave satisfactory growth results. In the practical tests (20 per cent protein ration) where this mixture furnished 60 per cent of the total protein the gains made were nearly as good as those made when sardine meal furnished the protein.

BONE PRODUCTS

GREEN CUT BONE consists of fresh bones, with more or less adhering meat, put through a special grinder. This is a very palatable feed, comparing very favorably with fresh meat and blood, for hens are cannibalistic enough to like raw meat and fresh blood. Green cut bone makes a good source of animal protein, containing about 30 per cent protein, but there are certain disadvantages which restrict its use. Ordinarily, it is not available regularly and constantly and in sufficient quantities. Then, too, the bones must be free from any contamination or diarrhea and other bowel trouble will result. In warm weather it might be a difficult problem to keep the meat adhering to the bone from becoming tainted. One must also consider the expense of grinding.

Where it was fed in the fresh form and in amounts so that the birds obtained sufficient protein, varying results in production have been obtained. In the main, however, the feeding of fresh cut bone has compared favorably with meat scraps.[68] However, some form of dry animal food is likely to prove safer and more satisfactory and cheaper, or, when available, green cut bone can be used as part of the animal protein.

"Cooked Bone Meal is the dried, ground product, obtained by cooking undecomposed bone in water at atmospheric pressure

just enough to remove excess fat and meat. It shall contain not more than 25 per cent protein and not less than 10 per cent phosphorus (P). The label shall include a guarantee for protein, calcium (Ca), and phosphorus (P)."

Bone meal or granulated bone is ordinarily not used as a source of animal protein but is considered as a mineral product furnishing calcium phosphate. The raw bone contains considerable protein, but it is of low biologic value and has not given satisfactory egg production.[69] (For other bone products which are phosphorus carriers see Chap. 7.)

EGG PRODUCTS

EGGS are a possible source of animal protein although they are too costly for this purpose. However, incubator infertiles have long been recognized as a valuable feed for chicks, and are thus used.[70] The infertile eggs can also be boiled hard, run through a food chopper without removing the shells, and mixed with enough mash to keep from being sticky.

ALL-EGG MEAL[71] is a product used with favorable results as a source of protein. It may be made from the by-products of hatcheries consisting of the infertile, dead-germ, and dead-in-the shell eggs. The eggs are boiled, passed through a sausage mill or food chopper, mixed with mash and fed, or dried and reground into a meal. The final product contains about 35 per cent protein, 30 per cent fat, and 30 per cent minerals.

MISCELLANEOUS ANIMAL PRODUCTS

INSECTS. On range, the birds have opportunity to eat the natural animal foods, which are insects and worms. Poultry is fond of worms, larvae, grubs, and beetles. They could be used as food, but, naturally, where large numbers of birds are involved, it is not practical to furnish them. It is not advisable that poultry eat too much of this class of food.

LIVE SNAILS, which contain about 20 per cent protein, have been reported as giving favorable results when fed to ducks.[72]

SILKWORM CHRYSALIS FLOUR, a by-product of the silk industry, has been reported from Italy[73] as being an excellent substitute for meat and fish meals. It contains about 54 per cent protein. Unextracted silkworm pupae meal, when used as the sole protein concentrate in Germany,[74] did not prove satisfactory. Since the pupae contain a large amount of fat, the silk-

worm pupae meal should be fed after the fat has been removed.

ANT EGGS consist really of the pupae and not the eggs. They have been used by game-keepers, especially in Europe.[75] They can be used either fresh or as a semi-dried preserves for poultry or winged game.

LOCUST MEAL,[76] which contains about 45 per cent protein, has been reported as a possible source of protein for chicks, since it has proved to be as palatable as fish meal. However, it is not so efficient as fish meal. The consumption of grasshoppers by turkeys has been reported as causing mortality.[77] This was thought to be due to an enteritis caused by the legs of the insects.

HYDROLIZED TANNERY WASTE, a product obtained by hydrolizing waste resulting from the scraping of hides in tanneries and containing 44.7 per cent crude protein, was reported by the California Station[78] as producing 10 per cent fewer eggs than meat scrap.

HYDROLYZED FEATHERS as a feed for chickens were used at the Kansas Station.[79] It seemed to delay molting in hens for a short time. The conclusions drawn were that hydrolyzation was too expensive and added nothing of importance to present-day rations. The Iowa Station[80] reported that the addition of sodium sulphide-treated feathers to a basal cereal diet resulted in a rate of growth significantly greater than that produced by the basal diet. Feathers contain a large amount of cystine and supplement corn oil meal.

"POULTRY BY-PRODUCT MEAL consists of the nonrendered, clean, wholesome parts of the carcass of slaughtered poultry, such as head, feet, undeveloped eggs, gizzard and intestines exclusive of feathers, and gizzard and intestinal content." Chicken scrap thus produced has been reported as comparing favorably[81] with two other sources of supplementary protein when fed to chicks for 8 weeks.

HOOF MEAL was fed to hens by the Missouri Station[82] but did not prove an adequate source of protein Production was only 75 eggs as compared with 128 for sour milk.

The Wisconsin Station[83] concluded that chicks are able to utilize powdered swine hoofs when finely ground and mixed with other protein feeds. It "teams" well with soybean oil meal. It appears to be a satisfactory substitute for meat scraps and fish meal in practical chick rations. The Ontario Agricultural College[84] reported that hoof and horn meal was a fairly adequate substitute for 5 per cent of meat meal, when the ration contained

5 per cent of fish meal and 3 per cent of dried buttermilk, but was not satisfactory in the absence of fish meal. It did not exhibit any supplemental effect when fed in combination with corn gluten feed, sunflower seed oil meal, soybean oil meal, or linseed oil meal. All the vegetable proteins were markedly superior to the hoof and horn meal.

PROTOZOA OF THE RUMEN. Experiments, reported from Italy,[85] indicate nutritive values for the dried ciliate infusoria from the rumen of a sheep and from dried bacteria from the same source. The favorable influence is attributed to the protein contributed by the supplements.

UREA. Experiments reported from Germany[86] indicated that amide flakes could not replace or save albumin in rations for hens. High percentages of amide were eaten with relish and did not cause any disturbance of health. The Wisconsin Station[87] reports that simple nitrogen compounds, such as urea, can be used in calf rations as a substitute for protein, but not in rations for chicks, guinea pigs, and rats. The Hawaii Station[88] found definite protein starvation, characterized by retarded growth, when urea was fed as the supplement to a low-protein ration to chicks. Apparently it can be fed only to ruminants, since certain bacteria in the rumen probably use the nitrogen for growth, converting it into protein in their bodies. Then the bacteria pass along the alimentary canal until they are digested. Similarly, the Nebraska and Oklahoma stations[89] showed that amide nitrogen was not utilized by growing chicks.

NECESSITY FOR AND USE OF ANIMAL PROTEIN

The common use of animal protein concentrates in poultry feeding shows the high regard in which they are held, and experimental evidence points to a superiority of animal over vegetable protein concentrates in poultry rations. The difference is probably due to several factors: (1) the quality of protein as represented by the amounts and kinds of amino acids present; (2) the essential mineral elements; (3) the comparative vitamin content. In a National Research Council Report[90] it is concluded that the "available evidence rather clearly demonstrates that the effectiveness of animal protein concentrates, in promoting maximal production in swine and particularly in poultry, is not due primarily to their protein constituents, but rather to their higher contents of certain vitamins, of calcium, of phosphorus, and possibly of some of the micro-nutrients."

Many early reports showed better egg production with rations containing animal protein. However, when the mineral deficiencies of the vegetable protein were made up the results were very satisfactory.

Poor hatchability[91] has been reported for rations not including feeds from animal source. This has usually been due to a deficiency of vitamins, chiefly riboflavin, vitamin B_{12}, and unidentified factors.

Cannibalism, which was reported as the result of a deficiency of animal protein in the diet, was reported cured by the addition of 5 per cent of meal meal to the diet.[92]

The value of animal protein food in chick feeding has long been recognized. As early as 1898, W. P. Wheeler of the New York Experiment Station[93] reported that a ration in which 2/5 of the protein was supplied by animal food was much more profitably fed than one containing only protein from a vegetable source.

When rations with plant and animal proteins were compared for feeding on range in Bulgaria,[94] little difference in the rate of growth was observed over a period of 100 days. The Nebraska Station,[95] comparing protein concentrates from animal and vegetable sources for growing chicks, reported that the percentage rate of gain, the gain per gram of nitrogen, and nitrogen retention were greater at 60 days of age in the lot fed the animal protein concentrate.

In more recent comparisons the differences between growth of chicks on plant versus animal protein rations are not so great This is due to more complete information which permits the supplementation of vegetable protein feeds to make up known deficiencies such as calcium, phosphorus, methionine, lysine, riboflavin, vitamin B_{12}, and others. The chief importance or necessity of animal feeds[96] under these conditions lies in unidentified vitamins or factors which they might supply.

AMOUNTS OF ANIMAL PROTEIN

The question arises as to the amounts of animal protein feeds that should be included in poultry rations

MATURE BIRDS. Some protein concentrates are needed in the ration to give good egg production.[97] In 70 early experiments, comparing rations containing a protein concentrate in the form of animal protein feeds with others not containing the protein concentrate, all favored the feeding of animal proteins. The average increase in egg production was 116 per cent

Northern Ireland[98] reports a laying mash of cereals, supplemented with $\frac{1}{2}$ per cent of common salt, as capable of supporting egg production at a level of more than 200 eggs per bird per annum, with no return from the addition of supplements of soybean meal to the ration.

In the earlier experiments in which animal protein was the only supplementary protein it was necessary to feed sufficient amounts to meet the various requirements such as protein and possibly minerals and vitamins. For that reason egg production was closely related to the consumption of meat scrap or other form of animal protein.[99] Approximately 10 per cent of animal protein in the ration gave the best results with birds in confinement. *With birds on free range this amount could be safely and* economically reduced. This accounts in part for the almost universal practice in England[100] of reduced amounts of meat or fish in the mash.

A shortage of animal proteins during World War II made it desirable to know to what extent the animal protein could be decreased and the soybean oil meal increased without materially affecting production, hatchability, and feed efficiency. A number of experiments[101] have been reported in which small amounts of animal protein, in combination with soybean oil meal as the protein supplement, have given as good egg production as larger quantities. Usually the hatchability was also satisfactory. In some experiments[102] the egg production has been satisfactory on a high soybean oil meal ration, but hatchability was reduced. In one experiment conducted at Cornell[103] no difference in either egg production or hatchability was obtained between rations supplying all the supplementary protein from soybean oil meal and part from soybean oil meal and part from meat scrap.

GROWING BIRDS. Where no extra protein, as animal protein,[104] is included in the ration, the chicks make very slow growth, lack uniformity, and are not thrifty. For example, in experiments at Cornell, the chicks receiving no animal protein feed had at a certain period the average weight of 0.49 pound, those receiving meat scrap supplement weighed 0.66 pound, and those receiving milk weighed 0.78 pound.

During early life, chicks require more protein than later. Therefore, the protein as supplied by an animal protein concentrate is usually higher in the starting rations.[105] For the later periods, less protein and animal protein feeds are required.[106]

A shortage of animal protein during World War II also made it desirable to known to what extent the animal protein could be

decreased in chick rations without affecting growth, mortality, and feed efficiency.[106] A number of reports show very good growth of chicks on rations containing no animal protein supplements. The animal protein itself is not essential for good growth in chickens. It may be easier, however, to provide all the nutritive essentials when some animal protein is included.

Comparing rations containing some animal protein concentrates with those containing all soybean oil meal as the supplementary source of protein, it was found that the results in practically all instances were in favor of the rations containing some animal protein. Summarizing the reports as published by a number of experiment stations, Almquist found that the relative growth on the soybean meal rations represented 55 to 99 per cent of the growth obtained on the good rations. To equal the best growth, the addition of some animal protein concentrates to the soybean oil meal rations seems to be necessary.

COMPARISON OF ANIMAL PROTEIN FEEDS

Differences exist in the results that are obtained when the various kinds of animal protein are fed as the sole source of supplementary protein.

MATURE BIRDS. Representative results of different animal proteins in poultry feeding, as expressed in egg production per hen per year, are shown in Tables 11 and 12.

The evidence tends to indicate that combinations of two or more animal proteins are equally effective and often preferable

TABLE 11. REPRESENTATIVE RESULTS OF DIFFERENT ANIMAL PROTEINS IN POULTRY FEEDING. EGG PRODUCTION PER HEN

Meat Scrap	Liquid Milk	Dried Milk	Tankage	Fish Meal	No Protein	Reference
145	175	...	134	...	113	Idaho Circ. 27, 1922
...	146	...	115	...	89	Idaho Bul 134, 1924
135	135	...	...	128	33	Ind. Bul 182, 1915
136	140	...	...	...	61	Ind. Bul 218, 1918
179	...	...	184	...	60	Ind. Bul 227, 1919
...	165	189	...	...	57	Ind. Bul. 258, 1921
156	153	165	...	...	...	Ky. Bul. 260, 1925
107	131	...	...	...	65	Mo. Circ. 79, 1916
134	127	...	...	...	60	Mo Circ. 82, 1917
120	129	...	...		57	Mo. Bul. 155, 1918
117	125	112	120	...	61	Mo. Bul 225, 1924
139	...	140	125	...	...	Mo. Bul. 272, 1929
134	...	171	...	...	...	Pa. Bul. 206, 1926

TABLE 12. COMPARATIVE RESULTS OF DIFFERENT ANIMAL PROTEIN FEEDS IN EGG PRODUCTION

Animal Protein Feed	Exp. 1	Exp. 2	Exp. 3
20% dried buttermilk in mash	166	...	...
20% meat scraps in mash	151	147	150
20% milk albumin in mash	163	...	...
20% dried skimmilk in mash	151	...	...
20% meat meal in mash	...	141	...
20% fish meal in mash	...	137	132
20% meat scrap mash plus liquid milk	165	177	...
20% meat scrap mash plus semi-solid buttermilk	...	161	...
11% meat scrap mash plus liquid milk	...	161	...
Mash plus liquid milk	147	...	...
Mash plus semi-solid buttermilk	164	...	...
Liquid milk (no mash)	...	161	...

All pens received grain.
Comparative Results of Different Animal Protein Feeds in Egg Production, M.S. Thesis, by A. L. Romanoff, Cornell University, 1926.

to using any of them singly.[108] In a comparison of dried milk, meat and bone meal, and combinations of both as protein supplements for egg production, Henderson ranked the groups as follows: "milk," 152 eggs; "combinations," 139 eggs; "meat and bone meal," 121 eggs.

Mortality and the condition of the birds, as well as egg quality, must also be considered. In general, there is not much difference between the various sources of animal protein, except that milk tends to give better average weights of hens, and liquid milk slightly larger eggs.

The cost of the feeds must also be taken into account, since the real measures of the value of the various feeds are the cost per dozen eggs and especially the returns per hen above feed cost. However, it does not cost much more per hen per year to feed the higher-priced feeds, and, if production is enough higher to be significant, the increased number of eggs will probably more than offset the higher feed cost. In most cases combinations of meat and milk products gave higher returns above feed cost than either one used separately.

GROWING BIRDS. Combinations[109] of two or more forms of animal protein feeds, in many cases, have given better growth than one alone. The supplementary value of milk has been especially evident, owing probably, in many cases, to the vitamin B complex. The extent of any benefits of combinations will depend upon completeness of the ration in other respects. It may

be desirable that at least two sources of animal protein feeds be included in the ration for young stock.

Where the chicks are reared on good range, it will not be necessary to use so much animal protein feeds. This is particularly true where small numbers are reared, as under general farm conditions.[110]

MEASURING THE VALUE OF PROTEIN CONCENTRATES

The value of any particular product is influenced (1) by the nature of the raw materials and (2) by the conditions of manufacture. Both the quality of the proteins of common protein supplements used in poultry rations and the riboflavin content were reported as being influenced by the process of manufacturing them.[111] Process of manufacture, however, affected the riboflavin content to a greater extent than the protein quality. To maintain maximum riboflavin potency a relatively low temperature and a relatively short time are required in cooking and drying the raw materials. Flame drying, because of the extremely high temperature, was found deleterious to proteins, but the other processes of manufacture did not materially affect protein quality. Dry process meals were found to have a higher protein and a lower ash and ether extract content than wet process meals.

No loss in supplementary protein nutritive value was observed in certain fish meals after 10 months of storage in paper, cotton, and burlap bags.[112]

The relative values of the different protein concentrates must, in the main, be determined by feeding trials.

The Cornell workers,[113] by determining the relative efficiency for growth, suggested relative protein efficiency as an expression of the utilization of the proteins of a protein supplement The relative protein efficiency was obtained by determining the percentage of protein stored by normal chicks during the seventh week of age, dividing the percentage storage by that of a standard casein diet, and multiplying by 100 The value of the protein is thus expressed in relation to the value of casein, which is represented by 100. On this basis the samples studied showed the following values: casein, 100; dried skimmilk, 100; white fish mean, 104; sardine meal (domestic), 98, Menhaden fish meal (steam-dried), 91; soybean oil meal (expeller), 89, meat scrap (55 per cent protein), 82; meat scrap (50 per cent protein), 73; corn gluten meal, 61; ground soybeans, 58.

The Washington Station[114] has also reported a method for determining the gross value of protein concentrates. This method consists of depleting the protein reserve of the chicks for a period of 2 weeks by feeding a suitable chick ration, complete in all the known nutrients except protein. The level of protein in the depletion ration is 8 per cent and is derived from plant sources. The experimental rations consist of the depletion ration to which is added a sufficient amount of the supplement to bring the protein content to 11 per cent. The experimental period is 2 weeks, and the results are compared with commercial casein, which is given a gross protein value of 100. The gross values for some of the samples studied were: Alaska herring fish meal, 101; dried buttermilk, 91; dried skimmilk, 78; Manchurian soybean meal (hydraulic), 57; domestic soybean meal (expeller), 46; meat meal (Brazilian), 43; meat and bone meal (Brazilian), 32; dried Alaska peas, 27; dehydrated alfalfa, 25.

The Nebraska Station[115] reported the following relative biological values for the different protein concentrates:

Dried buttermilk Fish meal Casein	AA
Meat and bone meal Soybean meal	A
Blood meal Cotton seed meal	B
Linseed oil meal Corn gluten meal	C
Gelatin	D

The California Station[116] has reported on the use of analyses of concentrates considering intact protein, protein decomposition products, indigestible protein, and hot-water-soluble protein. These analytical characteristics were found to exhibit a good correlation with nutritive value for chicks when assigned the relative values of 100, 40, 0, and 40 respectively Such analytical methods offer a possibility for the rapid laboratory determination of protein quality in commercial concentrates. The cystine, tryptophan, and hydrogen sulphide content of the protein concentrates could not be used as a basis for predicting their nutritive values.

From the results of Canadian reports[117] it would appear that a satisfactory evaluation of the biological value of animal pro-

tein concentrates might be obtained from the microbiological assays for amino acid content based on acid hydrolysis of the total protein corrected for the indigestible and nonprotein fractions.

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CHAPTER 7

POULTRY FEEDS

VEGETABLE PROTEIN SUPPLEMENTS

In general, cereal grains alone have not given satisfactory results in growth or egg production, owing largely to deficiencies in protein and minerals. However, with birds on range in Northern Ireland,[1] a production of approximately 200 eggs from White Wyandotte pullets has been reported for a ration of cereals, supplemented only with minerals. The further addition of a protein-rich feed resulted in an additional increase of 13.5 per cent in egg production.

Protein has always been considered an important constituent of the ration. As shown in Chapter 6, animal protein products have consistently given satisfactory results. It is only natural, therefore, to inquire about the value of vegetable protein feeds, particularly where they are home grown or cheaper. Since early feeding trials have generally demonstrated the superiority of protein-rich feeds from animal origin, as compared with those from a vegetable source, it is of value to know to what extent vegetable proteins can be used and to find out in what respects they are deficient.

The results of some of the early experiments[2-6] with vegetable proteins were not favorable, but these could probably be attributed to deficiencies of minerals or amino acids. On the other hand, other experiments[7,8] indicated satisfactory results, particularly for laying hens.

A number of protein-rich vegetable feeds have been used in feeding trials with poultry. However, cottonseed meal and soybean products have been fed most extensively, probably because of the supply of the cottonseed meal, and of the favorable results obtained with the soybean.

COTTONSEED MEAL

COTTONSEED MEAL FOR MATURE BIRDS. A large number of experiments have been conducted using cottonseed meal in rations for mature hens.[9]

Results in Egg Production. A review of the early experiments

involving the use of cottonseed meal shows that most of the trials do not give favorable egg production as compared with the trials in feeding some animal proteins, such as meat or milk. It is probable that many of these productions are low because of mineral deficiencies.[10] Table 13 gives some of the results.

TABLE 13. AVERAGE EGG PRODUCTION PER HEN FROM COTTONSEED MEAL TRIALS

Meat	Cottonseed	Cottonseed Plus Minerals	Reference
135	60	83	Mo. Circ. 82
117	48	81	Mo. Bul. 225
107	67	117	Mo. Bul. 236
143	45	136	Mo. Bul. 256
122	49	106	Ohio Monthly Bul. 7-8, 1924
	117	134	
174	97	154	Okla. Rept., 1925-1926
	106	131	

Even though cottonseed meal cannot be used alone as the protein-rich supplement to the mash, it may be possible to use it in combination with animal protein feeds. Several stations report tests where a combination of meat scraps or tankage and cottonseed meal gave better results than either one alone.

Poorer hatchability has been reported for the hens fed cottonseed meal. This has been attributed to the harmful effects of the components of cottonseed pigment glands, including gossypol, and a deficiency of lysine.[11]

Greater mortality and smaller egg size have been reported in some of the trials in the pens receiving cottonseed meal.

Effect of Cottonseed upon Egg Quality. The most serious objection to the use of cottonseed meal in the poultry ration has been its effect upon the quality of the egg,[12] although in many trials this effect is not mentioned. An early report by Roberts and Rice[13] indicated that the eggs laid by nitrogen-fed hens (cottonseed meal ration) were small and had a disagreeable flavor and smell, watery albumen, an especially small, dark-colored yolk, with a tender vitelline membrane, which turned black after being kept several weeks in brine.

Cottonseed meal spots occur on the yolk and can be seen when candled. The market value is thus affected because of the unattractive appearance. Yolks may vary considerably in appearance, ranging from a few tiny brown spots to a condition where the brownish area may cover a large part of the yolk.

In some reports it has been stated that the eggs that were seriously affected with the cottonseed meal spots had a strong flavor which made them objectionable for most uses.

Cottonseed meal affects the keeping quality of eggs in storage,[14] which holds true also for eggs that do not show the cottonseed meal spots. Heavy losses have been reported with eggs held in storage because of dark yolks that resulted from the heavy feeding of cottonseed meal.

Sherwood reported that the substance in cottonseed meal that causes eggs to deteriorate in storage was probably something closely associated with the cottonseed oil. Experiments conducted at the Louisiana Station indicated that gossypol is the factor responsible for olive-colored yolks. The characteristic olive color is due to a chemical combination of gossypol with *ferric iron*, released from the egg proteins of the yolk. In the fresh yolk insufficient ferric ions are present. During storage, sufficient iron is liberated to form the olive color. The addition of soluble ferric salts to the ration containing cottonseed meal prevents the absorption of gossypol by the hen and the formation of olive yolks in the stored eggs.

The degree of yolk darkening during storage increased as the *free gossypol content of the diets increased*. *Bound gossypol* did not cause discoloration of the eggs. Eggs from hens fed gland-free cottonseed flour do not develop egg-yolk discoloration. The storage quality of eggs produced from hens fed screw-pressed cottonseed meal or isopropanol extracted meal was satisfactory whereas olive-colored yolks and pink albumen were observed when a hydraulic meal was fed.

GENERAL SUMMARY. As far as egg production is concerned, the results are variable. The use of cottonseed meal seems to be warranted as a substitute for meat and tankage. Cottonseed meal is useful for the production of eggs when the eggs are to be used fresh but not when they are to be stored because of the effect upon the quality of the eggs. If cottonseed meal is used in the ration for laying hens, adjustment should be made for its mineral deficiency. It is also advisable to use it only to furnish part of the protein-rich feed and not to substitute it entirely for meat scraps or similar feeds.

COTTONSEED MEAL FOR YOUNG CHICKENS. As early as 1899 the New York (Geneva) Experiment Station[15] reported that when the deficiency of mineral matter was made good by the addition of bone ash, the vegetable food ration for chicks equaled or somewhat surpassed in efficiency a corresponding ration con-

taining three-eighths of the protein from animal food.

Workers at the Rhode Island Station[16] reported that the animal protein ration produced faster growth when compared with cottonseed meal, gluten feed, gluten meal, and oil meal. However, the addition of ash constituents greatly improved the vegetable protein feeds.

Some experiments indicated slower growth with a cottonseed meal ration.[17] Other experiments show good results,[18] especially when properly supplemented with animal protein. A combination of protein supplements seems to be more important than the percentage of cottonseed meal used.

The method of processing affects the nutritive value of cottonseed meal.[19] The physiologically deleterious components of cottonseed are segregated in the pigment glands. Hence gland-free meals and some processed meals have supported excellent growth. Solvent meal has been reported slightly superior and hydraulic meal inferior to expeller meal.

SOYBEAN PRODUCTS

Soybeans are being raised in greater abundance, partly because of their value in crop rotations. It is one of the most valuable of the leguminous seeds. The two important commercial products derived from soybeans are soybean oil and soybean oil meal. Soybean oil meal, the product remaining after removal of the oil, should not be confused with soybean meal, which refers to ground whole soybeans.

SOYBEAN OIL MEAL. There are several processes employed in making soybean oil meal: (1) solvent or new process, in which the oil is removed by use of some chemical that will dissolve oil; (2) hydraulic or old process, in which the oil is removed by hydraulic pressure; (3) expeller method, in which the oil is expelled by a friction process which generates heat.

Soybean oil meals, processed from frost-damaged immature beans,[20] have been fed to chicks with results that have compared favorably with results from those fed normal meal.

The soybean contains a high percentage of physiologically good protein, a considerable amount of energy-yielding material, and a fairly liberal supply of the fat-soluble and water-soluble vitamins. The soybean protein has been reported to be quite as valuable as the casein of milk.[21]

The soybean is deficient in minerals, however, and sodium chloride and calcium compounds need to be added. Soybean oil

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The soybean is deficient in minerals, however, and sodium chloride and calcium compounds need to be added. Soybean oil

a combination of soybean oil meal and animal proteins or their equivalent has given good growth.[40] This is particularly true for the starting ration.

In rations containing large amounts of soybean oil meal, Hammond[41] concluded that as much as 15 per cent of cottonseed meal, corn gluten meal, peanut meal, or ground hempseed may be used to replace an equal weight of soybean oil meal for growing chickens.

The Western Washington Station[42] reported that rations in which soybean oil meal supplied all the supplemental protein caused "pasting up" in chicks to a much greater extent than did rations in which herring fish meal or casein furnished the supplemental protein. The amount of "pasting up" which occurred varied with different samples of the meal. Less of it was caused by the solvent process meal. The droppings of chicks fed soybean oil meal rations were of a stickier consistency than were those fed fish meal or casein rations. The retardation in growth caused by this condition was only slight at 4 weeks of age.

GROUND SOYBEANS. Ground Soybeans have been used in laying rations. They are not as efficient as the soybean oil meal, however, and in most trials did not give as good results as the soybean oil meal or animal protein.[43] The Delaware Station found that ground soybeans were relished and readily eaten and that they maintained excellent physical condition It was found furthermore than when the laying ration contained over 7 per cent of ground soybeans, the egg production per hen decreased and mortality increased. On the other hand, the Indiana Station found ground whole soybeans as satisfactory as soybean oil meal. In this work, the hens were allowed free range over a grassy plot at all times.

Ground Soybeans are not so effective in the feeding of young chickens[44] as soybean oil meal, but they can be used if they are relatively cheap. The quantities used, however, must be limited. The Delaware Agricultural Experiment Station concluded that if the ground soybeans, supplemented with bone meal, do not replace more than one-third of the meat scrap, the results will not be seriously affected. Experiments conducted at Cornell[45] and Nebraska[46] showed the relative protein efficiency of ground raw soybeans to be approximately 65 to 70 per cent of that of soybean oil meal, when expressed on the basis of growth response

Ground whole cooked soybeans effectively replaced 5 per cent of soybean meal and 5 per cent of cottonseed meal when fed at a 20 per cent level in a broiler mash during a 9-week growing period at the Oklahoma Station.[47]

PEANUT PRODUCTS

PEANUT MEAL[48] as a source of protein has generally given satisfactory results, especially when the deficiencies were overcome. The deficiencies of peanut meal are minerals,[49] methionine, and lysine.[50]

Experiments at the Alabama Station[51] showed that the feeding of peanuts, without shells, to either hens or chicks gave poor results, thought to be due to the inability of the chicks to utilize large amounts of fat.

CORN PRODUCTS

GLUTEN FEED[52] has not given good results in egg production, especially in the earlier work, although some improvement has been shown when minerals were added. This is probably due to the fact that gluten feed is deficient in protein quality and in riboflavin. Other results[53] indicate that corn gluten feed is suitable as a partial protein supplement in rations for growing chicks as well as mature birds.

GLUTEN MEAL. Corn gluten meal[54] may be used in rations for laying hens and chicks when properly supplemented to compensate for its deficiencies. It might be lacking in arginine, lysine, and tryptophan[55] and in some of the members of the vitamin B complex. Used in large amounts it is not as satisfactory as soybean oil meal.[56] When corn gluten meal was used in rations for growing chicks and poults the degree of pigmentation of the shanks and skin was markedly increased.[57]

CORN OIL MEAL. Several experiments were conducted at the Iowa Station[58] to determine the nutritive value of corn oil meal and feather protein. The chicks fed a basal diet, supplemented with large quantities of corn oil meal (over 30 per cent), grew at a very slow rate, utilized their feed inefficiently, and suffered a high mortality. The inclusion of up to 30 per cent of corn oil meal did not affect palatability of the feed. The addition of cystine or lysine increased the growth.

LINSEED OIL MEAL

Early experiments with linseed oil meal have not shown good results.[59] The addition of minerals improves linseed meal but does not make it so efficient as animal protein.[60]

Linseed meal is deficient in lysine.[61] It also contains a factor or factors detrimental to the growth and health of chickens. It has been suggested that the presence of mucilage in linseed oil

meal is much lower in calcium and phosphorus content than the animal proteins. Hence it was soon discovered that the mineral content of the protein supplements was as important as the protein content.[22]

A ration deriving its protein chiefly from soybean meal has also been shown to be deficient in the sulfur-bearing amino acids, especially methionine.[23]

A ration composed largely of corn and soybean oil meal is likely to be deficient in vitamins,[24] particularly riboflavin, pantothenic acid, niacin, choline, vitamin B_{12}, and unknown factors present in animal products. The vitamin deficiencies have been reported as being corrected by the microbiological action produced in built-up litter.[25]

The variable results obtained with soybean oil meal indicated differences in nutritive value in various samples of the meal depending largely upon the conditions of manufacture.[17,26] Raw soybeans and also soybean oil meals processed at low temperatures contain proteins of low nutritive value, whereas soybean oil meals prepared at higher temperatures contain proteins of higher nutritive value.[27] The color and flavor of the meals are not infallible criteria of their nutritive value, but a raw, beany flavor is indicative of an insufficient amount of heat and a resulting inferior protein efficiency.

The raw soybeans contain a trypsin inhibitor[28] which is inactivated by heating. Heating also renders the soybean nutrients more available or digestible.[29] On the other hand there is the possibility of impairment of feeding value by overheating.[30] The methionine and lysine seem to be particularly affected. Overheating may cause the production of brown-colored substances that appeared to be related to more liquid and sticky droppings produced by the birds.[31]

Experiments conducted at the Colorado Station[32] showed that raw soybeans had a goitrogenic effect when fed to chicks. This effect was partially inactivated by heat. Iodine counteracted the effect on the thyroid. Egg production and hatchability were low, and it is suggested that the poor reproduction was related to the goitrogenicity of soybean meal.

Increasing the level of soybean meal in the diet of broilers has been reported to increase water consumption.[33]

Laboratory estimations of the biological value[34,95] of soybean meal have been reported Underheated soybean oil meals contain a substance or substances which significantly delay coagulation time of the blood of chicks.

SOYBEAN OIL MEAL FOR HENS. Egg production has been satisfactory when soybean oil meal was used either as a partial source or the sole source of supplemental protein.[35,36] Satisfactory body weight has also been obtained.

The results of some of the early experiments comparing soybean oil meal with meat scrap and fish meal were not favorable for the soybean oil meal because minerals were a limiting factor. When minerals were properly supplemented,[36] the egg production with soybean oil meal was increased and made comparable with that secured with rations containing animal protein. Some of the representative results are shown in Table 14.

TABLE 14. INFLUENCE OF SOYBEAN OIL MEAL ON EGG PRODUCTION

Soybean Oil Meal Plus Minerals	Animal Protein	Source
125	139	Ind. Rept. 1923
151	140	Ind. Bul. 293
125	139	Ind. Bul. 293
144	133	Ind. Bul. 293
138	132	Ind. Bul. 293
173	186	Ind. Bul. 293
135	153	Ind. Bul. 293
139	143	Mo. Bul. 256
132	139	Mo. Bul. 272
133	142	Mo. Bul. 285
223	210	Scottish Jour. Agr. 11
194	232	Scottish Jour. Agr. 11
164	166	Harper Adams Bul. 4

The feeding of soybean oil meal to breeders has shown variable results in hatchability.[37] Soybean oil meal as the only supplemental protein has usually not been satisfactory. However, when hatchability results were unfavorable they could usually be attributed to some deficiency such as riboflavin, vitamin B_{12}, or other essential nutritive factors.

SOYBEAN OIL MEAL FOR FEEDING THE YOUNG STOCK. Soybean Oil Meal. The results from the feeding of soybean oil meal to growing chickens and poults have been very satisfactory. The chick can utilize soybean oil meal protein to advantage. Some trials[38] indicate just as good results with soybean oil meal as with animal protein, provided that the minerals are adjusted and that the protein is the only varying factor. On the other hand, a number of experiments[39] report superior results for animal proteins, such as meat scraps and dried buttermilk. In general,

meal is one of the factors.[62] The toxic principal in linseed oil meal has been destroyed by water treatment or overcome by additional pyridoxine.[63] Flaxseed treated with ammonia and stored before processing was found superior to untreated flaxseed meal.[64]

Supplementing the linseed meal with a small amount of fish meal has improved its feeding value.[65]

OTHER VEGETABLE PROTEINS

Other vegetable protein feeds have been used in poultry feeding. The Idaho Station[66] lists pea meal, alfalfa meal, and bean meal in the order mentioned. Bean meal gave smaller eggs than the others.

BROCCOLI MEAL[67] as the only protein supplement did not produce good growth but when combined with soybean oil meal maintained fair growth and livability.

CASTOR BEAN. Castor bean oil meal[68] was toxic when fed to chicks either untreated or after steaming. However, repeated extraction resulted in a meal which gave normal growth.

COCONUT OIL MEAL. "Cocoanut oil meal or copra oil meal is the ground residue obtained after the extraction of part of the oil from the dried meat of the cocoanut. It must be designated and sold according to its protein content." Coconut oil meal, plus minerals, was used by the Pennsylvania Station[69] as a vegetable protein to replace a large part of the animal protein In the Philippines,[70] copra meal did not prove satisfactory for growing chicks or ducklings. With an increase in the amount of copra meal, mortality increased while food consumption and weight increase diminished. A report from England[71] indicated that coconut meal up to 20 and 25 per cent of the mash was satisfactory for laying hens.

HORSE-BEAN (*Vicia Faba L.*) MEAL[72] as the principal protein source is very deficient in the sulfur-containing amino acids and deficient to a lesser degree in a number of others However, when properly supplemented improvement in growth and feathering were obtained.

IPIL-IPIL SEED MEAL[73] is not a satisfactory protein supplement for chick rations, but it can be improved by water treatment.

LESPEDEZA SEED. The Missouri Station[74] reported that whole lespedeza seed proved a satisfactory substitute for soybean oil meal in chick rations, when fed at levels not to exceed

15 per cent. More than this amount produced sticky droppings. The whole lespedeza seed proved superior to ground lespedeza seed as a supplement to meat scrap.

MUNGO. The mungo bean has been used in the Philippines[75] in rations for growing chicks. Fair results were obtained by replacing 20 to 40 per cent of the shrimp meal by mungo. Mungo as the sole protein supplement caused high mortality and small size in chicks.

The Oklahoma Station[76] reports satisfactory growth, egg production, and hatchability when mungo beans were properly supplemented. They were also satisfactory as a source of protein for turkey poults.

MUSTARD. Mustard seed oil meal in chick rations has given variable results.[77] O'Neil indicated significantly lower weights with as small quantities as 2.8 per cent. Kondra and Hodgson reported normal growth on mashes containing up to 9 per cent of the meal.

PALM NUT. Corozo palm nut oil meal[78] can be fed to chicks as a partial supply of protein. It was found to supplement sesame oil meal and cottonseed meal.

PEAS. Peas have been used in feeding hens at the Idaho Station.[79] The egg production was better than where no protein concentrate was fed, but not so good as the production in the animal protein lots. Ground peas needed to be supplemented with animal protein to meet the requirements of laying hens. Methionine was shown to be the principal growth-limiting deficiency of pea protein. Pea meal as the main protein source for chicks[80] is unsatisfactory. However, when supplemented with fish meal or casein to supply methionine growth was improved.

RAPESEED OIL MEAL. Rapeseed oil meal[81] is the byproduct in the production of oil from rapeseed. Feeding experiments with hens in Germany indicated that, on the mash containing 15 per cent of rapeseed cake, food consumption was reduced. A maximum of 10 per cent of this ingredient is recommended. Rapeseed oil meal can be fed in limited amounts in chick rations. When larger amounts are included in the ration mortality and a reduction in the rate of growth during the early period of the bird's life resulted. It has been shown that the rapeseed oil meal contains a goitrogenic agent. This meal may be used for growing birds after hot water extraction or when supplemented with iodine. It has been suggested that rapeseed oil meal may be more suitable for fattening and finishing.

SAFFLOWER OIL FEED. Safflower oil feed is the ground

residue obtained after the extraction of the oil from whole safflower seed. Safflower oil meal[82] when properly supplemented gave good growth. It is deficient in lysine and methionine.

SESAME OIL MEAL. "Sesame oil meal is the ground residue obtained after the extraction of part of the oil by pressure from sesame seed as produced under reasonable milling conditions. It must be designated and sold according to its protein content." Poor growth has been reported on sesame protein alone,[83] owing primarily to a deficiency of lysine and vitamin B_{12}. In connection with other proteins (soybean meal and fish meal), relatively richer in lysine, sesame seed is capable of supporting optimal chick growth rates.

Sesame Cake Meal has also given satisfactory results when fed to laying pullets.[84]

SORGHUM GLUTEN MEAL[85] is not satisfactory as a major protein supplement since it is deficient in the amino acids arginine, lysine, methionine, and tryptophan. When properly supplemented it has produced the same results in chick rations as corn gluten meal and could be used in place of it.

SUNFLOWER SEED. Sunflower seed oil meal[86] is the by-product in the production of oil from sunflower seeds. The chief deficiency appears to be lysine. It has proven satisfactory in chick and turkey starter rations especially when used in combination with other proteins. Sunflower oil cake and meal have also been satisfactorily fed to mature birds.

SWEET LUPINES. Ground sweet lupine seeds, which contain about 45 per cent protein, have been fed to chickens in Germany.[87] It was shown that one-third or more of the usual fish and meat meal could be replaced by ground seeds of yellow sweet lupines.

Sweet blue lupine[88] did not prove satisfactory in replacing part of the soybean oil meal in a chick ration.

TUNG OIL MEAL. Tung oil meal is the residue remaining after the oil has been expressed from ground dehulled tung fruit. It has been reported as being unpalatable and containing some irritating material which has a harmful effect on the mucous membrane of the intestines. The Florida Station[89] reported that feeding tung oil meal to chicks was unsatisfactory.

WHEAT GLUTEN[90] Wheat gluten meal and wheat gluten feed are deficient chiefly in lysine, but when properly supplemented they can furnish part of the protein in chick rations

YEAST. Experiments in Poland[91] showed that the protein of yeast had a nutritive value almost equal to that of milk protein and greater than that of all other vegetable proteins The egg

yield was increased 6 to 10 per cent, and the weight of chickens and ducklings 2 to 12 per cent, according to the proportion of yeast-treated feeding stuffs in the ration.

Results from Germany[92] indicate that a 5 per cent yeast-supplemented ration had 17 per cent higher egg production that a similar pen receiving the same amount of skimmilk but no yeast.

Distillery yeast[93] in amounts of 10 to 15 per cent has been reported satisfactory for layers and growing chicks.

The feeding results with torula yeast have been variable,[94] depending to some extent upon the conditions under which it is produced and the wastes utilized in its production. The results indicate that it is a satisfactory source of protein and riboflavin.

NUTRITIVE VALUE OF VEGETABLE PROTEINS

Evans and St. John[95] reported that the chemical protein quality index, as used for animal proteins, appeared to give good indication of the relative protein nutritive value for soybean oil meals, cottonseed meals, and Alaska peas, with the exception of the overcooked soybean oil meals. A coefficient of correlation between gain per unit of supplementary protein and the chemical protein quality index of +0.946 was obtained. A high coefficient of correlation of +0.928 between the gain per unit of supplementary protein and the percentage of glutelin (insoluble in water, saline solutions, or alcohol, but soluble in very dilute acids and alkalies) was obtained for the heat-treated concentrates. A determination of the percentage of glutelin may offer a chemical means of estimating differences in the protein nutritive values of soybean oil meals and, in combination with the percentage of residual protein, the extent of heat denaturation of the soybean proteins.

Laboratory estimations[34] of the value of soybean meal have been reported. Fluorescence and urease activity gave a satisfactory evaluation of the nutritive value for chicks of solvent soybean oil meals but not of expeller meals.

A chemical index (total gossypol content plus N soluble in 0.02 sodium hydroxide) for cottonseed meal[96] gave good correlation with chick growth rate.

GENERAL SUMMARY FOR VEGETABLE PROTEINS

Animal protein feeds have been somewhat more effective than vegetable protein feeds for both young and mature stock. The lack of good results from vegetable proteins has probably been

due to a deficiency, chiefly in minerals, certain amino acids, and vitamins. Partial substitutions have given very satisfactory results. With an increasing knowledge of requirements for these factors and a more exact knowledge of the nature of the more common poultry feeds, it should be possible to find combinations of feeds which include larger proportions of vegetable feeds. In general, the vegetable proteins need to be supplemented with minerals, particularly calcium and phosphorus, and vitamins, of which they contain considerably less than the animal proteins.

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CHAPTER 8

POULTRY FEEDS

GREEN FEEDS AND VEGETABLE PRODUCTS

The importance of green food in poultry feeding was first observed because of the response of birds when allowed to range in the spring after being confined during the winter. The resulting spurt in egg production was due probably to the warmer weather and exposure to the sun as well as access to green food. Again, it was observed that production was retarded late in the summer and in the fall when the natural supply of green food became low.

The green growing part of plants has long been recognized as the basis for animal nutrition. The nutritional significane of grass has been pointed out by Elvehjem and Sober [1] They show that grasses contain appreciable amounts of many of the well-known nutrients and are rich in unknown factors. Assays show them to contain significant amounts of carotene, vitamin C, vitamin E, vitamin K, thiamin, riboflavin, pyridoxine, pantothenic acid, niacin, biotin, and choline. The mineral content is favorable. The protein content may be as high as 30 per cent. Young grass is of higher nutritive value than older herbage since it contains more protein and vitamins (especially riboflavin) and less fiber. Leafy green vegetation[2] and the fresh juice of forage crops have been shown to contain growth factors

In comparative trials,[3] where green food was furnished during the winter as compared to feeding no green food during that period, often considerable differences in production were secured

Various reasons have been given to account for the benefits of green food One of the first explanations given for its value was that it acted as a tonic, stimulant, or invigorator. The specific effect was not designated, but indications were that it had a beneficial effect on the condition of the bird and thus produced more eggs or flesh. It was also believed that green food stimulated the appetite and in that way encouraged greater food consumption and consequently larger production. It promoted activity and was a help to digestion. Sometimes it acts favorably in furnishing additional bulk to the ration In this respect, it is necessary to

distinguish between furnishing the nutritive elements of true green food and mere succulence. In some instances the feed is more palatable in the succulent form as, for example, when feeding germinated or sprouted oats instead of the dry oats.

The health of the hen is influenced also by the feeding of green food. This is shown by greater mortality as well as decreased egg production when green food was not supplied.[4] It has also been reported[5] that the feeding of green food will result in prevention of molt and reduction of summer culling which, with the other factors mentioned, will mean a saving of money.

Greater mortality[6] due to coccidial infections has been found in birds ranged on bare lots than in birds ranged on pastures. Birds on pasture carried heavier worm infections, but were able to withstand heavier parasitic burdens.

The feeding of green food frequently keeps birds busy, and in that way might help to prevent or overcome picking and other forms of cannibalism.

Perhaps the most important fact about green feeds, however, is that they are rich in vitamins. Green feeds, as a group, is the only group which is well supplied with all the vitamins. The other groups of feeds usually are deficient in one or more of the vitamins. The feeding of green food has improved hatchability. This improvement in hatchability is probably due to vitamins.

KINDS OF GREEN FOOD

GRASS RANGE OR PASTURE is the natural method of providing green food, and, where it is supplied abundantly, is probably the best method. Clover and alfalfa ranges are preferred, primarily because the green stuff is available over a longer period of the year. They do not grow up and become tough and unavailable, as grass does. Frequent mowing of grass, however, will help to keep it tender.

For poultry pastures, plants capable of forming a dense, hard-wearing, and lawn-like turf are desirable.[7] Wild white clover and ladino clover are suitable legumes. Grasses suitable for poultry turf are perennial rye grass, meadow grasses, the fescues, creeping bent, and crested dog's-tail. However, poultry does not like the plants after they have become aged and woody and will then only eat them as a last resort Turkeys[8] prefer ladino clover, but other grasses can be satisfactorily used for grazing.

Crampton and Forshaw[9] presented evidence to show that the

feeding value of the herbage of any single species changes during the growing season. Herbage grown during spring and fall, when plant growing conditions are favorable, has excellent feeding value. Herbage grown during midsummer has lower nutritive value, owing apparently to a reduction in the availability to the animal of the carbohydrate fractions.

A mixture of grasses is usually recommended for poultry pastures. The grasses most commonly used are Kentucky bluegrass, Canada bluegrass, timothy, perennial rye grass, wild white clover, and ladino clover. Regardless of the mixture, the pasture must be mowed frequently so that young grass is kept constantly growing up from the bottom.

Where range is depended upon for green stuff, the units must not be too large or too concentrated. Hens will not range far from the house so that usually the grass adjacent to the house is soon entirely eaten, whereas further away it grows and matures.

Pasture for Growing Birds. The benefits of range rearing may be attributed to improved health due to better nutrition, more sanitary conditions, and more favorable management.

If the chicks are restricted on feed nutrients, either because feed is withheld or because the ration is deficient, they will consume more grass and select those types which will supplement their ration. Thomas[10] fed chicks both high- and low-protein rations and observed that the grass in the run of the low-protein lot was heavily grazed and kept in check, while the herbage in the run of the high-protein lot was untouched. Furthermore, the clover content of the sward in the run of the low-protein lot was reduced to a greater extent than in the run of the high-protein lot. Gutteridge, O'Neil, and Pratt[11] presented evidence to show that the pasture was utilized to an increasing degree on the lower levels of protein. The high animal protein ration (17 per cent) appeared to have been adequate in most respects since the pasture of the group on this ration was only very lightly grazed. There was a suggestion that the vegetable protein groups felt the need of supplementing their ration to a greater degree than the groups fed animal protein through an increased intake of pasture grass.

Chicks on good pasture eat a considerable amount of grass and thus save on the amount of grain and mash required. Reports from poultrymen have indicated feed savings up to 35 per cent. Most of the experimental results, however, do not show savings of this magnitude.[12,16] The feed savings reported range

from 5 to 20 per cent. The larger savings were usually obtained when the feeding time was restricted. However, with drastic feed restriction the weights of the pullets usually were lower.

Poultry can utilize fresh, young grass[13] but is unable to deal as effectively with large amounts of it as are the other farm animals. The amount appears to be limited by the capacity of the birds to break down the fiber. Temperton and Dudley, in feeding grass to growing stock, found that when 10 per cent of the mash was replaced by its equivalent in grass on the dry matter basis (representing about 1/3 the gross food intake), much of the grass was found in the droppings in an apparently little altered condition and there was a marked reduction in the rate of growth. However, the grass-reared birds were quicker in maturing. According to a report from Finland, Pihkala concluded that poultry can obtain only 5.5 to 7.0 per cent of its food requirements from pasture. In the feeding of turkeys, Darrow and Morgan reported that the amount of feed saved by the use of range was 9.1 per cent for the Bronze turkey and 3.1 per cent for the Small Whites.

The actual amount of feed saved is not the only benefit of pasture. Perhaps of even greater value is the saving in feed cost since good pasturage permits omission from the ration of ingredients which may be more expensive, such as vitamin carriers, milk by-products, alfalfa meal, and animal protein.[14] In fact, some of the reports indicate that whole grain plus minerals proved to be a satisfactory ration when fed to birds on good pasture.

Variable results have been reported for birds reared on grass.[15,16] However, when compared with rearing on bare ground or in confinement pasture-rearing of pullets has shown some advantages. The birds may be heavier at maturity and usually show deeper pigmentation. Birds on pasture usually consume less food and thus make more economical gains. Mortality, sexual maturity, and subsequent egg production are not influenced much by pasture.

Pasture for Mature Birds. The value of pasture land for mature birds is indicated in experiments conducted in Germany,[17] where a saving of 34.3 per cent of the total cost of feeding Leghorn hens was made, when the birds were kept on open pasturage. Another pasture group required during the summer, when feeding in the open was possible, 32.1 per cent less feed to produce the same weight of eggs than the group without open pasturage.

Reporting on ranges for the laying flock, Berry[18] showed the largest returns over feed cost were received when the laying flock was provided with an alfalfa range. However, the returns were greatest when the flock was allowed access to the range for only 2 hours each day. This short daily period provided sufficient green feed, but the birds did not eat enough green alfalfa to lower egg quality.

The Kentucky Station[19] reported that bare or bluegrass range, in connection with a complete all-mash ration for laying hens, did not influence feed consumption during the summer period after the grass had matured and partly lost its green color. However, the hens consumed 10 to 20 per cent less feed when given access to a bluegrass range during the spring growing season. The bluegrass range during the growing season increased egg production but did not influence weight or hatchability of the eggs, or the health and weight of the hens. Stephenson and Bryant[12] concluded that the use of a sod range during the laying period is preferable to keeping the birds in strict confinement, and that it seems advisable also to keep the birds confined to the house during the fall and winter months unless there is good green pasture available.

Thomas[10] reported that Rhode Island Red layers fed a low protein ration supplemented the protein deficiency by consuming the clover and dandelions instead of the perennial rye grass. Temperton and Dudley[20] showed that the feeding of grass in comparatively large amounts to laying pullets did not have any adverse effects on health but did decrease egg production and produced a very deep-colored egg yolk.

Good pastures for laying hens[21] have generally improved egg production and hatchability, reduced the feed requirements and lowered mortality. However, the yolk color was usually darker. Pastures of oats, Italian rye grass, Japanese mustard, and Kudzu and Bermuda grass have proven of value.

Supplements of green feed have been reported[22] not to affect the interior quality of eggs, as measured by the albumen index, percentage of firm albumen, height of firm albumen, or yolk index. The only marked effect of feeding fresh grass is to increase the quantity of pigment in the yolk. Ovarian hemorrhages[23] leading to the production of blood and meat spots have been reduced by allowing hens access to range.

GREEN CROPS. Alfalfa and clover furnish a good feed when cut green and fed directly to the hens. These feeds are especially desirable for birds closely confined or running on bare yards.

They furnish a good source of green food in summer when second- and third-cutting alfalfa and clover are available. Soybeans and the green cowpea plant have supplied green succulent fodder.[24] Green forage crops have been used as a substitute for three-fourths of the mash for laying hens.[25]

GRAIN PASTURE. For this purpose any of the grains may be used. It is available chiefly in the early spring, its main disadvantage being its temporary nature, inasmuch as most of the shoots soon become old and tough. Rye, sown in the fall, or winter wheat is often used for this purpose.

LAWN CLIPPINGS are usually not available in large quantities but furnish good green food, especially if they contain some clover. Where lawns of any size are maintained in connection with the poultry farm, it is wise to catch the clippings for this purpose.

CABBAGE is a succulent green food. The vitamin content is not so great as in the kinds of green food with thin green leaves. The outer, greener leaves also contain more of the vitamins. It makes an excellent green food although more expensive than some other forms. The small and unmarketable heads may be used to advantage in poultry feeding.

SAUERKRAUT is another form in which cabbage may be fed. It has been fed to young chicks by putting the sauerkraut on a plate and sprinking feed over it. Mature birds may be fed 3 to 4 pounds a day per 100 hens. The sour taste seems to act as an appetizer. The kraut is made in the usual way, except that a little less salt is used.

RAPE is often used where birds are confined. It is fed much the same as cabbage. Sometimes the birds are given access to the field itself later in the season. Rape gives a very dark color to the yolk of the egg, which, in some cases, has been considered an objectionable feature.

KALE makes a very good green food because of its palatability and productivity. It will yield 20 or more tons of green material per acre. It is used very extensively on the Pacific Coast, where the thousand-headed variety is chiefly grown. It is sown in several plantings in order to give a succession, and in some sections it is thus available the year round. It may also be utilized as shade.

In England,[26] egg production was not satisfactory with the feeding of marrow stem kale to laying pullets. The health of the birds was not influenced and no substantial economy in purchased foodstuffs resulted.

OTHER GREENS, such as lettuce, onions, spinach, beet tops, swiss chard, and the like, may be used to excellent advantage as green food. Waste leaves of cabbage, cauliflower, broccoli, and other plants can be utilized.

SPROUTED GRAINS[27] make it possible to provide green food at any time. The grain sprouter has been referred to as the poultry silo because the sprouted grains are ordinarily used as a winter and early spring source of green food. Oats are the common grain used for sprouting. Sprouted oats also provide a satisfactory way to use oats, since the absorption of water, while not increasing the nutrient, makes the grain more palatable and digestible. One hundred pounds of oats will absorb enough water to make about 350 pounds of the sprouted grain. There is an actual loss of dry matter[28] in sprouting oats so that the advantage of the process is to produce a succulent green food. Sprouted rye[29] was not as satisfactory as sprouted oats.

GERMINATED OATS have been used in place of the sprouted oats. Results of feeding germinated oats to Leghorn pullets at Indiana[30] indicate these things. Germinated oats appeared to increase egg production during the winter months, but they had no significant influence upon egg production during periods of 10 months' duration. No benefit was derived from increased fertility and hatchability of eggs. There was no evidence to indicate that the fiber in the germinated oats was of any particular importance. On the other hand, the Delaware Station[31] reported greater mortality and lower production from pens receiving no germinated oats as compared with ones being fed the same in some tests, and little influence on egg production or mortality in other tests.

Experiments with laying hens in Italy[32] proved that the winter lay was improved by feeding germinated grain The control birds lost weight, whereas the birds fed the germinated grain gained weight.

SILAGE[33] is frequently suggested as a means of supplying green food. Favorable results have been reported although frequently the value of silage is overestimated

The West Virginia Station concluded that because of the beneficial effect upon hatchability in the first test and upon egg production in the second, it would seem that, when available, a small amount of corn silage may be fed to laying hens in winter to advantage. On the other hand, there have been some cases of digestive disturbances They might have been due to the fermentation. As a form of succulence, corn silage has been used

satisfactorily by some poultrymen by mixing it in the mash after boiling it.

Grass silage of various types has been given considerable attention. Payne and associates at the Kansas Station[15] reported larger net returns per bird when pullets were fed immature cereal grasses, both in fresh and in ensiled forms. The feeding of oat grass silage resulted in the production of olive-colored egg yolks, commonly classified as "grass eggs." Darker yolk color was observed when hens were fed silage as compared with fresh cereal grasses. Restricting the silage consumption to 2 to 3 pounds daily per 100 hens and feeding a high quality of silage eliminated grass eggs. There was no significant effect of feeding silage upon egg production.

The Tennessee Station[34] concluded that silage feeding as a supplement to the regular rations was a desirable practice. The advantages of silage feeding included greater zest for eating and higher daily feed consumption, increase in weight over poultry not receiving such silage, and better physical condition as determined by appearance, vitality, weight production, egg production, and post-mortem examinations.

The New Jersey Station[35] reported that grass silage fed at the rate of 4 pounds per 100 birds per day prevented the usual drop in hatchability when alfalfa leaf meal and dried buttermilk were removed from the ration. The use of grass silage as a substitute for milk and alfalfa in chick rations up to a month of age was not fully satisfactory because of the inability of the young chick to handle such bulky material.

Temperton and Dudley[36] concluded that, in the feeding of grass silage to laying pullets, the two chief difficulties encountered were in cutting the grass sufficiently short and in getting the birds to eat the silage in sufficient quantity to effect a material saving in mash.

The West Virginia Station[37] concluded that considering the labor involved in making immature silage and the experimental evidence showing little or no beneficial results from feeding the silage to chicks in batteries, to growing pullets and layers confined in pens, poultry rations can be supplemented more efficiently by other vitamin carriers, especially for supplying riboflavin.

A variety of crops can be made into silage. They include alfalfa, the clovers, timothy, redtop, orchard grass, bluegrass, oats, wheat, barley, rye, lawn grass clippings, peas, and soybeans. Good silage has been made with molasses (60 to 80

pounds per ton), phosphoric acid (20 pounds of 70 per cent per ton), or ground grain (150 to 200 pounds per ton).

In the feeding of silage to mature birds the usual recommendation is to feed 4 to 6 pounds to 100 hens daily. They frequently will consume much larger quantities, but this is usually neither necessary nor desirable.

ROOT CROPS AND TUBERS of various kinds have been used in the past to furnish succulence and to take the place of green food. However, their use has declined because it has been found that many of them furnish little, if any, vitamins. Therefore, they do not function as true green foods.

Mangle beets are liked by the fowls but furnish little, of any, vitamins. They would, therefore, furnish only succulence. They are a cheap and easily handled succulent. They can be stored easily in a root cellar or put where they will keep until spring. Mangles are usually fed about midday and given in such amounts that the hens will eat readily the rest of the day.

Carrots, turnips, rutabagas, and other roots may be fed. A good way to feed these types of crops is to shred them. Carrots contain considerable vitamin A. The Michigan Station[38] reported that 4 to 5 pounds of carrots daily per 100 birds provided an adequate amount of vitamin A and that this product was a satisfactory substitute for alfalfa products in the laying ration during the winter feeding period.

Potatoes do not furnish a source of green food They furnish succulence and may be used, however, after boiling and mixing with mash, but they function the same as grain and ground feed. They can also be fed raw.

The essentials of a good root cellar are protection against freezing, proper ventilation, and drainage.[39]

HAYS[40] have been used in recent years in place of green foods for poultry. The legume hays, particularly, have been fed for this purpose. In 1928 the Ohio Station stated that the best substitute for green food is a high-quality, leafy, immature-cut legume hay. The Washington Station reported that alfalfa hay, chopped into 1-inch lengths, proved an excellent substitute for green food. When it was kept before the birds at all times, they consumed 8 pounds per bird per year. Well-cured, second- or third-cutting alfalfa hay is used Soybean hay has also been fed with good results. It should be cut when the seeds are just beginning to form in the pods. All the hays are usually cut into ½- to 1-inch lengths and kept available to the hens in wire baskets or containers.

Clover or alfalfa chaff or leaves can be used either in the dry form, giving birds access to it as in the form of hay, or they may be steamed or soaked and mixed with a wet mash.

DRIED GRASSES of various kinds have been fed to poultry with satisfactory results. In general, the dehydrated grasses or those not subjected to too much heat have given the best results. This is probably due to the better retention of their vitamin content, especially vitamin A.[41]

Alfalfa Meal has been the most widely used and has given good results. Ordinary alfalfa meal is of little benefit. Considerable variation[42] is found in the composition and nutritive value of different samples of alfalfa meal. This is particularly true as regards fiber, protein, ash, vitamin A, and riboflavin. Dehydrated alfalfa meals are generally superior to sun-cured meals, especially in regard to the vitamin content. A good alfalfa meal should contain a high percentage of leafy material, have a high protein and ether extract and a low fiber content, and be fragrant and of a bright green color. Usually not over 5 per cent of alfalfa meal is included in the mash.

The South Dakota Station[43] indicated that the optimum percentage of alfalfa meal lies between 10 and 20 per cent and it will substitute for either bran or middlings, but egg production falls off if it is substituted for both. Better results were obtained when it was combined with middlings. The New Mexico Station[44] reported as satisfactory egg production from the birds receiving alfalfa meal as from those on green alfalfa range. The United States Experiment Station in Arizona[45] showed that sun-cured alfalfa meal was a poor substitute for fresh alfalfa, that sun-cured alfalfa leaf meal was more satisfactory than sun-cured alfalfa meal as a substitute for fresh alfalfa, and that whole alfalfa hays were unreliable as substitutes for fresh alfalfa.

The Wisconsin Station[46] reported increased egg production and hatchability by including alfalfa meal in winter rations. Alfalfa meal was better than dried cereal grass, although either one was effective.

The Nebraska Station[47] reported that artificially dried sudan-grass meal could replace alfalfa meal in a ration for growing chicks. The Delaware Station[48] concluded that locally produced dehydrated ground clover and perennial grasses could be used in broiler rations in place of western sun-cured alfalfa leaf meal. Experiments reported from South Africa[49] show that cow-pea hay meal could replace 8 to 10 per cent of alfalfa meal in chicken rations up to 10 weeks of age.

The Kentucky Station[50] concluded that because of the bulkiness of air-dried bluegrass, due to the high fiber content, it was not a satisfactory ingredient for all-mash rations for growing chicks but that the bluegrass should be fed ad libitum as a succulent feed. Leaf meals of Korean lespedeza, alfalfa, and lespedeza sericea replaced mixed wheat feed, on a basis of equal parts of protein in the feeding of growing chicks, but could not replace wheat feed and either dried skimmilk or meat scrap on a basis of equal quantities of protein.

The Mississippi Station[51] found that kudzu meal and kudzu leaf meal compared favorably in chemical analyses with alfalfa meal and alfalfa leaf meal of good grade.

Other meals which have been fed with satisfactory results are brome grass, crested wheat grass, western wheat grass, brome-alfalfa mixture and sudan grass meals,[52] ladino clover meal,[53] desmodium meal and pigeon pea fodder meal,[54] mangrove leaf meal,[55] ramie meal,[54,56] kikuyu grass meal,[54] and banana leaf meal.[54] Koa haole leaf meal and fresh green koa haole leaves[57] can be fed in moderate quantities. Creeping indigo leaf meal[58] depressed egg production, body weight, and feed consumption of laying birds and growth of chicks.

DRIED VEGETABLE WASTES[59] have been reported as being good sources of protein, carotene, and riboflavin. The Delaware Station concluded that all the wastes used (dried pea vines, lima bean vines, turnip tops, broccoli, and carrot tops) may be fed to broilers or other growing birds at as high a level as 8 per cent in place of alfalfa meal. The broccoli and turnip tops produced a significantly greater degree of pigmentation than the alfalfa meal. All the vegetable wastes were more palatable than the alfalfa meal. When used in a breeder ration cannery by-products[60] have improved a ration containing no alfalfa but was not quite as good.

Semi-solid vegetable wastes[61] have also been reported as being valuable for poultry feeding.

Dried pea vines,[62] high quality bean vine meal,[63] and dehydrated celery tops[64] have been reported to compare favorably with alfalfa meal. Dehydrated flat pea forage[65] was shown to have no value as a protein supplement for growing chicks.

DRIED BEET PRODUCTS.[66] Dried beet pulp as well as similar products, such as dried cabbage, are not relished by fowls and are of questionable value in poultry feeding.

Dehydrated beet leaves[67] have been fed satisfactorily at low levels. At higher levels there was a depressing effect due to the

oxolic acid content which could be overcome by increasing the calcium in the ration.

PIMIENTO PEPPER has been fed to poultry by the Georgia Station.[68] It gives a rich yellow color to the shanks, skin, and fat, the amount of color depending on the amount of pimiento fed. The eggs also had higher hatchability.

MISCELLANEOUS GREEN FOODS. It is probable that almost any kind of green plant material can be used in feeding chickens, as well as other animals. Dried nettles have been reported from Italy[69] to be beneficial for both chicks and hens. In California, the spineless cactus has been used as greens for poultry. No injury was apparent in the hen after rhubarb leaves[70] were fed for 30 days as a supplementary feed. Leaves and young shoots of centrosema, ipil-ipil, and sweet potato and ipil-ipil leaf meal have been advantageously fed to ducks.[71]

EPSOM SALTS has sometimes been mentioned as a green food substitute. It is not a substitute for green foods but was used as an alternative for its laxative effect.

COMPARATIVE EXPERIMENTAL RESULTS

In comparing mangels, clover, and sprouted oats as green food, the Kentville (Canada) Experimental Station[72] reports clover as more productive than mangels, which were better than sprouted oats. In studying substitutes for fresh green food, Elford[73] found the value of the various feeds studied to be in the following order: alfalfa meal, sweet clover meal, potatoes, mangels, sprouted oats, Epsom salts.

In a study of root crops at the Fredericton (Canada) Station,[74] it was found that swedes or raw potatoes were superior to mangels, all of which gave better results than Epsom salts.

In a study of the effect of certain green food substitutes (including sprouted oats, yellow mangels, alfalfa leaves, alfalfa leaf meal, and cod liver oil) upon egg production and hatchability at the New Hampshire Station,[75] all substitutes studied were valuable sources of vitamin A, as measured by health and egg production. The cod liver oil pen excelled in egg production. The alfalfa leaf meal pen gave the highest hatchability, followed closely by the pen receiving alfalfa leaves.

In a comparison of chopped alfalfa hay with alfalfa leaf meal at the Ohio Station,[76] the egg production was somewhat better in the lot receiving the chopped alfalfa hay. The hatchability of eggs was practically the same in all lots.

Alfalfa leaf meal, sprouted oats, and germinated oats gave benefits in the order named as regards egg production, per cent hatch, and mortality at the Kansas Station.[77] In this experiment, the basal ration was deficient in vitamin A since white corn was used.

Experiments conducted in Germany[78] indicated that all kinds of green foods and substitutes may be given to laying and breeding hens with good results.

NECESSITY OF GREEN FOOD IN THE RATION

Formerly green food was considered as being necessary or desirable in the poultry ration.[79] Now less emphasis is placed upon it.

Since green foods owe their importance largely to the fact that they are important vitamin carriers, their necessity obviously depends to a large extent upon the ration fed and the conditions under which the birds are kept. With a proper adjustment of the ration, it is possible to minimize the importance of including green foods. At the Cornell Station, there was no apparent benefit in egg production during the winter from adding green food when cod liver oil and milk were included in the ration. They, in part, furnished the same elements which were supplied by green foods. There was some indication, however, that hatchability was benefited by the inclusion of green foods in the ration.

With an increase in our knowledge concerning vitamins, their distribution and functions, we shall probably be able to adjust our rations so as to use little or no green foods and still secure optimum results in all respects. Some reports[80] indicate that normal growth of chicks may be obtained on rations containing no green plant tissue. It has also been shown[81] that green feed is not necessary in rations for good egg production.

In surveys made in connection with pullet management campaigns, it has been noted that there was no difference between the flocks receiving green or succulent feed and those receiving none. It should be noted, however, that the rations fed usually contained some alfalfa and milk.

In an economic study of poultry farming in New York,[82] including surveys from 123 farms, for the year ending September 30, 1930, it was found that, apparently, there was no difference in egg production per bird resulting from the use of green food or germinated oats. "It is believed by some that green feed or germinated oats increase feed intake. At times succulent

green feed may serve as an appetizer, but from these data there seems to be some question whether it is worth the trouble required in feeding it."

	No Green Food or Germinated Oats	Green Food Only	Green Food and Germinated Oats	Germinated Oats Only
Number of farms	52	51	5	15
Eggs per hen	142	149	139	143
Number of birds	1542	1265	1640	1507
Per cent lay October December	22	24	19	21
Pounds of feed per bird	82	84	83	80

GROWING GREEN FOOD

The attempt to provide green food from pasture for large numbers of hens has been gradually abandoned. Pasture cannot withstand the attacks of hens and is soon depleted. Instead, green food is grown in separate fields, harvested, and fed to the hens. In some instances severe losses due to ground contamination or predators have also encouraged confinement rearing, with the feeding of freshly cut green food, in place of range rearing.

Another important value of growing green food for chickens is the shade with which it provides them. Furthermore, the growing of crops helps to keep the ranges and yards in sanitary condition. For ranges, crops commonly grown are corn, soybeans, and sunflowers. For the cropping of yards and runs, rye, oats, and rape are usually planted.

POULTRY GREEN FOOD GARDENS AND CALENDARS. As a suggestion for the possible production of different types of green food for poultry, outlines for poultry green food gardens and calendars for the different sections of the country have been suggested.[83]

AMOUNTS OF GREEN FOOD FOR POULTRY

Where poultry is allowed to range, it will gather its green food. Usually it is allowed free range at all times. This is satisfactory where large fields are available and it is not necessary to conserve the feed supply.

Under unlimited range conditions, the birds will usually eat more green food early and late in the day. It was noted in Australia[84] that the pen with free choice (range) consumed more than the pens fed green stuff at noon, and that a considerable portion of it was eaten the last thing before the birds went to roost. The feeding of green stuff after the grain feed at night has resulted in a great improvement in the number of eggs laid. Therefore, on small ranges and when weather conditions are not favorable, the flock is frequently turned out to pasture only for an hour or two each morning or evening. If the flocks are large or the areas small for cropping, poultrymen may keep the birds confined and bring the harvested material to the birds each day.

The amounts of green food that the hens will consume each day varies considerably. One hundred healthy hens will often consume 12 to 15 pounds of green food each day if they have green food in ample supply continually. Also certain kinds are relished and eaten in larger quantities.

There is a question concerning the amounts of green food that are necessary or desirable. There is the possibility that we might, under some conditions, furnish too much green food That is true because we are furnishing a bulky feed containing 90 per cent or more of water and very small amounts of actual nutrients. Therefore, if we fill up the birds on this bulky feed, it is impossible for them to consume sufficient amounts of grain and mash in order to get enough of the nutrients to give maximum production. The New York Experiment Station[85] concluded that not more than one-third of the total ration can consist of coarse feeds, supplying about 10 per cent of the dry matter, without unprofitably diminishing production. For simple maintenance, much larger proportions can be used. From Finland[86] it has been reported that poultry cannot utilize more than 5.5 to 7 per cent of its annual food from pasture. Halnan[87] indicated limits of food saving for grass as 5 to 10 per cent for fowls, 16 per cent for turkeys, 18 per cent for ducks, and 100 per cent for geese.

Just what the optimum amount of green food is remains to be found out for different rations and different conditions Favorable results have been obtained where approximately 15 per cent of the total feed was made up of green food. Probably not more than 4 to 6 pounds of fresh green food should be fed a day to one hundred hens.

Where legume hay was used from November to May, the Ohio Station[88] reports a consumption of 6 pounds per bird for that

period. The Washington Station[69] indicates that where alfalfa hay, chopped into 1-inch lengths, was kept before the birds at all times they consumed 8 pounds per bird per year. Where succulent green feeds are used, it will require 12 to 15 pounds a year for each hen.

The amount of land necessary to grow the green food crops will depend upon the amount to be fed and the system of feeding.

RECOMMENDATIONS FOR PRACTICE

Some green food or its equivalent should be provided in the ration. Where a good range is available during the spring and early summer, the birds will get all they will need by pasturing. Particular attention, however, needs to be taken during the summer and fall when the grass begins to dry up. That is the time of year when green food is neglected even more than during the winter time. Under those conditions, the birds are outdoors, getting sunshine and exercise, but very little, if any, green food. At that time of the year, fresh-cut clover or alfalfa, rape, or any other green stuff can be fed, or the ration should be changed to supply the equivalent nutrients.

The use of dry products instead of the succulent forms is practised more extensively. This is usually done by feeding clover and alfalfa leaves or chopped green alfalfa hay in wire baskets or containers. Or alfalfa meal is added to the mash.

Since the green foods have an influence on the yolk color, the amounts fed must be limited where the market demand is for pale-yolked eggs. On this account, as well as its effect on palatability, alfalfa meal should be limited to 5 to 10 per cent of the mash. Where milk, yellow corn, some alfalfa hay or meal, cod liver oil, some animal protein, and a combination of the ordinary cereals are used in the ration, it is doubtful whether it is necessary to supply fresh green food, except when it is desired for its physiological effect or to keep the birds active to prevent picking.

When the fresh green foods are used, they are usually fed at noon in such amounts as the birds will eat before night. About 4 to 6 pounds per 100 hens a day are sufficient. When hay is fed, it is kept before the birds at all times in appropriate containers.

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CHAPTER 9

FACTORS IN MAKING A POULTRY RATION

In formulating rations there are many factors which must be considered, and the final result must be the best balance of all these factors. The best results cannot be obtained unless the ration is complete. In order to make a ration complete, it must meet certain requirements. The results obtained will be in proportion to its completeness.

ESSENTIALS OF A RATION

PROTEIN. The ration must contain suitable protein, both as to amount that is present and as to its nature or quality. It is essential that a certain minimum amount be present in the ration. Quantities can be larger without actual harm to the bird, but large quantities are not economical since the protein feeds are relatively expensive.

The protein must also be of correct quality. The proteins of various feeds differ because all do not contain the same amino acids, or where they contain the same ones they are not present in the same proportions. It is these differences that account for variations in quality of proteins. Furthermore, some of these amino acids seem to be more important than others.

The requirement for protein varies for different purposes. The growing animal needs more than the mature bird. Also the egg producer requires more than the nonproducer. The growing chick needs more protein in early life, when it is growing rapidly, than it does later on when relative growth slows down.

With our increase in knowledge, the requirements of a ration will be considered from the standpoint of amino acids, rather than from the standpoint of the more complex proteins, because it is really the deficiency or lack of any one of them which will limit results. Sometimes an increase in the percentage of total protein has resulted in improvement, not because the animal needed more total protein but because, by increasing the total protein, the amount of a certain amino acid which was deficient

in the smaller quantity was also increased. The same improvement could have been obtained without increasing total protein, but by making adjustments in feeds so as to bring the amount of that particular amino acid up to the necessary level. Until such time when we shall have more definite information on this subject, the safe practice is to use a reasonable variety of feeds in our rations, including animal protein feeds.

ENERGY. We must also supply an abundance of energy or fuel to keep the animal working properly, that is, to furnish energy to keep up body temperature and supply the body processes. This energy is often expressed as calories. It really is in part a matter of total food consumption. It is an important factor, since very often results in production, even with a balanced ration, are limited by a lack of food intake. The art of feeding consists in getting the birds to eat sufficient feed daily.

This energy is furnished usually in the form of carbohydrates and fat, which are considered the energy portion of feeds and are most economical for that purpose. Protein can be used for this purpose when fed in excess, but it is too expensive to use for energy. Besides furnishing energy, some of the fatty acids are also essential as such.

MINERALS. The ration must contain a suitable inorganic content. The practical poultryman must consider only the ones that might probably be deficient in his ration. When using a good ration, including natural feeding stuffs, the deficiencies are not many, being probably only sodium, chlorine, calcium, phosphorus, manganese, and iodine.

The sodium and chlorine are furnished by common salt. Calcium for eggshell formation is best supplied in the carbonate form. Oystershells and limestone will supply calcium. Where wheat by-products, meat scrap, and milk are used, there will usually be enough phosphorus. If phosphorus is determined to be necessary, bone meal or other phosphorus carriers are usually fed. Manganese is added as a manganese compound, and iodine as iodized salt.

Where minerals are necessary, they need to be added in only comparatively small quantities. It is possible to add too much of some. For instance, too much calcium will depress growth and increase mortality in chicks. Too much magnesium will upset the birds. An excess of fluorine is also detrimental. We also find in the body certain minerals balanced by others, so that excesses of any of them might so use up the others as to cause deficiencies that would not occur without such excesses.

Thus it is necessary to show judgment and precaution in respect to minerals as much as in handling other parts of the ration. The attitude of some persons, namely, that the addition of minerals will do no harm, even if they do no good, is not sound. Furthermore, the opinion sometimes encountered that if a small amount of minerals is good a large amount should be better is entirely unjustified.

VITAMINS. The ration must contain sufficient vitamins. The quantity of any of the different vitamins required by poultry varies with age and condition. Chicks and laying hens have a larger vitamin requirement than nonproducers. In this instance, however, molting hens should not be classified as nonproducers. Renewal of feathers should be classified as production, in the same way as growth and the laying of eggs, and it makes necessary the feeding of a liberal supply of vitamins.

WATER, AIR, LIGHT, AND SUNSHINE. The ration must contain an abundance of these factors.

Water. Very often the water supply is neglected Water is just as essential as feed. It is probably more necessary to keep in mind the importance of water for poultry than for other animals because of the drinking habits of poultry. Poultry needs to have water available practically constantly, because it partakes of only small amounts at a time. The larger farm animals can be watered once or twice a day, at which time they can drink sufficient amounts to carry them through the rest of the day

Water is necessary for all animals in order for them to carry on the various body activities. Water softens the food in digestion, aids in its assimilation, and is very important as a carrier in the distribution of the nutrients to the various parts of the body. It also functions in the various body secretions, and it helps to equalize body temperature.

Water makes up a large part of the body of the fowl itself. Probably around 55 to 60 per cent or more of the fowl's body is made up of water. The egg also has a very large water content; roughly about 65 per cent or two-thirds of the egg. A dozen eggs contain over a pint of water. Our ordinary feeds, such as grain and mash, which constitute the biggest part of the feed of the bird, are very low in water content, running usually somewhere around 10 to 15 per cent.

If water is not available, digestion and assimilation will be hindered. Secretions and excretions will be limited, the blood thickened, the body temperature raised, and finally death will result. An individual can live a longer period of time if only

water, rather than food, is available. The body tissues will be drawn upon for a supply of energy. If water is restricted, death will occur comparatively rapidly. A decrease in the supply or a restriction of water to poultry will decrease egg production and finally stop it. Egg production can be stopped almost entirely in the course of 48 to 60 hours by taking away all water.

Water should be available at all times. The hen drinks little at a time, but very frequently. It is necessary to have water available whenever there is feed available. With our present system of dry mash feeding, this means whenever the birds are off the roost. This might prove to be a very important factor during freezing weather and where artificial illumination is used.

The amounts of water that are consumed by birds are influenced by several factors. More water is consumed during hot weather. When the birds are producing more heavily under the same conditions of temperature, there is a higher consumption of water.

As far as actual water consumption is concerned, the following figures might be of interest in showing the amounts consumed daily by one hundred Single Comb White Leghorns.

November	11 quarts	May	20 quarts
December	11	June	22
January	13	July	20
February	15	August	16
March	17	September	14
April	19	October	13

Frequently the question is asked concerning the necessary temperature of the water. It should not be too cold in winter or too warm in summer. The chill should be taken off in the winter because, if the water is too cold, it does not encourage the hens to consume what is necessary. Oregon[1] reports that pullets drank 25.4 per cent more warmed water than cold water during freezing weather. Results at Idaho[2] indicate that hens in pens receiving water warmed to 40 to 50° F. consumed 20 per cent more water and gave an egg production decidedly in favor of the pens receiving the warm water.

Fresh Air. Sufficient fresh air must be supplied to furnish the oxygen for combustion or burning the feed and to carry off harmful waste products. The amounts of oxygen that are necessary depend upon the amount of food that needs to be broken down and metabolized, the amount of work that the individual does, and to some extent upon the temperature of the environ-

ment. The rate of metabolism determines the amount of oxygen that is required. The problem of providing air in the poultry house is to remove moisture rather than to furnish enough oxygen.

Light and Sunshine. Light and sunshine are two of nature's beneficial factors. These factors are not only the ultraviolet rays supplying vitamin D but some of the other rays of sunshine as well, which are being shown to be necessary for the well-being of the animal.

PROPER MECHANICAL OR PHYSICAL CONDITION. This factor has a bearing upon food consumption. The capacity of the fowl for food is limited and must be used to the best advantage if high production is desired. It is necessary to obtain adequate food consumption, which will not be accomplished unless the ration is palatable. This factor must, therefore, be kept in mind, since it is possible to have feeds with correct analysis that are not consumed in sufficient quantities. Consequently, we should avoid, or at least greatly restrict the amount of, such feeds.

Palatability depends to some extent upon the mechanical condition of the feed. Such characteristics as hardness of kernel, size of particle, stickiness when mixed with water, and bulkiness must be considered. Fowls do not like a very hard kernel. The particles should not be too large. When mixed with water, the ration should be crumbly. Thus large amounts of sticky feeds should not be fed.

As regards bulk, the ration should be reasonably filling and yet be able to pass readily through the body. A certain amount of bulk is necessary, especially with a concentrated diet, to enable the digestive juices to act readily. Furthermore, Sheehy[3] concludes that a feed mixture which, in addition to being complete, contains the proper amount of bulk and fiber, that is, is satisfactory from the mechanical aspect, controls feather plucking. The retention, by feed, of much water in the alimentary tube and the appearance in the lower gut of bulky, semi-liquid material, rather than dry dense residues, give a feeling of satiety which inhibits the development of cannibalistic tendencies. The birds must have a feeling of being comfortably filled. The perverted appetites of birds are frequently an attempted corrective against concentrated rations. On the other hand, too much fiber should be avoided, as the fowls have to grind everything taken into the body even though they digest little, if any, of the fiber. The fiber should be kept as low as possible. It should not go much beyond [illegible] per cent for the whole ration. Hence too much

oats, buckwheat, ground oats, wheat bran, alfalfa meal, and the like should not be fed. Too much fiber might cause constipation and inflammation of the digestive tract.

Shaw and Fisher[4] state that bulk or cubic content of a food is one of the first considerations in making a poultry ration meet feeding standards. Halnan[5] indicates the following:

> In trials with adult fowls it was found that the maximum amount of food they would eat as a mash was 290 cubic centimeters. The volumes of a certain number of foods were measured [Table 15] and variations from 33 c.c. to 185 c.c. per ounce were obtained according to the foods and their mechanical condition. Thus, one ounce of wheat measured 39 c.c. as grain and 50 c.c. as meal. One ounce of broad bran measured 185 c.c. dry and 140 c.c. wet.
>
> If it be assumed that the food capacity of an adult bird is 290 c.c. it would eat just over 2 ounces of wet bran daily, or 5.8 ounces of wheat meal. Any feeding standard based on a daily consumption of 4 ounces of food would, therefore, not work in practice if the volume of the food exceeded 73 c.c. per ounce. Actual cases of failure of egg production attributed to this cause have been brought to notice; the food was perfectly balanced and adequate for egg production on the assumption of a 4-ounce daily consumption, but failed because it was bulky, owing to the presence of excessive fiber, so that the bird was unable to consume the whole 4 ounces considered necessary. In constructing rations for any given purpose it is, therefore, essential to pay strict attention to the volume or bulkiness of the food.

Sheehy and Sheil[6] report that food consumption figures indicate an effort on the part of the group receiving a ration of low concentration to compensate for the comparative poverty of the ration by eating an excess of it, that the rate of growth increased progressively as the concentration of the mash was raised, and that the more concentrated mash conduced to greater egg production in the prewinter period. In an experiment conducted at Cornell in which three pens received the same ration, except that one contained 20 per cent of bran, another 20 per cent of standard wheat middlings, and the third 20 per cent of red dog flour, the average food consumed by the birds was in relation to the bulk of the ration. It required more grams of feed to produce an egg on the bran ration than on the middlings ration, which in turn required more feed than the red dog flour ration.

The ration must not be too coarse or too fine,[7,8] since texture will affect food consumption. In general, oats and barley should be fine ground, whereas corn and wheat should be ground coarse. Dusty feed is disliked. Medium to coarse rations have generally given better results than very fine or very coarse rations. More feed is wasted in the drinking water when birds are fed finely ground feed.

TABLE 15. WEIGHTS AND BULKINESS OF FEEDS*

Feed	Weight per Bushel, lb.	Bulkiness, cc. per oz. Dry	Wet
Alfalfa meal	. .	75	. .
Barley			
Whole	48	43	. .
Meal	. .	48	. .
Blood meal	. .	33	. .
Buckwheat			
Whole	48	50	. .
Meal	. .	45	. .
Corn			
Whole	56	41	
Meal	48-50	49	
Dried buttermilk	. .	45	
Dari			
Whole	56	40	
Meal	. .	50	
Peanut meal	. .	46	
Fish meal	. .	43	.
Gluten feed	. .	57	.
Meat meal	. .	45	
Millet			
Whole	50	37	
Meal	. .	52	
Dried skimmilk		48	.
Oats			
Whole	32	53	
Fine-ground	.	74	
Peas			
Whole	60	36	
Meal	. .	55	
Rye	56		
Soybean meal		52	
Wheat (hard)			
Whole	60	39	
Meal	.	50	
Wheat (soft)			
Whole	60	40	
Meal		47	
Wheat bran	20	165	140
Wheat middling (fine)	.	52	50
Wheat middling (coarse)	.	79	70

* Ministry of Agriculture and Fisheries, Great Britain, Bul 7

A condition called pressure necrosis[8,9] is attributed to the fine consistency of the ration fed. This condition is apparently due to a combination of factors. Birds closely confined in a brooder battery and fed finely ground food might eat the dry mash without taking sufficient drink to keep the mouth clean of adhering food material. The calcareous-like mass of accumulated food material in the mouth results in the pressure necrosis, causing the loss of either the upper or the lower mandible. The incidence of curled or deformed tongue[10] in turkeys was reported greater on fine mash than on coarse mash or pellets.

ABSENCE OF FACTORS HAVING UNFAVORABLE PHYSIOLOGICAL EFFECTS. It is necessary that nothing be present to cause the individual to function abnormally, since the best results can be obtained only when the individual approaches normality. It is entirely possible to meet all the conditions already stipulated and yet overcome their favorable influence by the presence of a toxic or poisonous substance.

Injury wrought by microorganisms in the alimentary tract would prevent the hen from making the best use of the feed. In fact, any condition of disease would to a greater or lesser degree cause pathological functioning.

We might also have such undesirable physiological effects as constipation or looseness of the bowels, caused by the inclusion of too much of certain ingredients in the ration. Some feeds, as oil meal, wheat bran, molasses, and dried whey, are laxative, whereas others, like cottonseed feed, are constipating.

FACTORS IN SELECTING THE RATION

Besides the essentials of a ration the following factors should be considered.

ADAPTABILITY. It is necessary to consider the purpose of the ration, that is, its adaptability for the purpose. The ration needs to be changed to meet the requirements of the particular purpose. Sometimes it means a change in the ration itself, that is, a change in the mixture or the ingredients of the ration. Sometimes it may mean a change in the method of feeding or the management of the birds. By adapting it to the purpose, we consider whether we are feeding for egg production, for growth, for fattening, for the handling of broody hens, the care of setting hens, or management of the birds during the molting period. It may mean the care of pullets for egg production under various conditions or at different times of the year, or it may mean the

management of breeders. Furthermore, we might be concerned with the feeding of other kinds of poultry such as ducks, geese, turkeys, pigeons, or game birds. Each of these conditions or purposes has some specific or definite considerations that need to be met.

NUTRITIVE RATIO OR BALANCE. Another factor to be considered is the nutritive ratio or the balance of proteins to carbohydrates and fat. This factor is important because the protein is necessary to build up the parts that are nitrogenous and because the protein cannot be replaced by the carbohydrates and fat. The carbohydrates and fat can be replaced to some extent by the protein, in that protein can furnish energy.

We must keep in mind the fact that the hen usually will not produce an egg unless that egg can be complete. Therefore, the quantity of production will be limited by the part of the ration that is present in lowest proportions. For example, if wheat alone is fed, as far as the protein is concerned, the hen would be able to lay one egg every 3 days; as far as the lime is concerned, she could produce one egg every 12 days; and as far as the carbohydrates and fat are concerned, she could lay 3 eggs every day. Another comparison which brings balance out quite clearly is the rating of feeds in terms of potential yolks and whites which different feeds can form. This method was used by Quisenberry.[11] For example, he estimated that 100 pounds of corn would be capable of producing 255 yolks and 134 whites, because corn is a wide feed containing more carbohydrates and fat. If corn alone was fed, there could be used only enough of the yolk material to produce 134 eggs, since the protein is a limiting factor. The remainder would not be used for that purpose. It might be stored as body fat, but most of the excess would not be used. It would be wasted. On the other hand, in meat scrap there are enough carbohydrates and fat in 100 pounds to produce 106 yolks and enough protein to form 1100 whites. Thus most of the protein could not be used. Hence a balance is needed in order to get as nearly as we can a combination of feeds which will supply a sufficient quantity of these various nutrients in proper proportions, so that there will not be an excess of any part to be wasted

What will be the probable results if an unbalanced ration is fed? The ration might be unbalanced in being too wide, containing too much of the carbohydrates and fats. If that is true, there will be failure to produce growth in young stock because we are limiting the muscle builder. At first, we would get a storage of

fat, because some of the excess carbohydrates and fat would be stored in fatty tissue; but this would not go on indefinitely, and some would be wasted. In mature birds egg laying would be retarded for lack of the protein to furnish the albumen or whites of the eggs. Again, we would probably get some storage of fat, but that also would probably be accompanied by a softness or flabbiness of the muscles of the birds. Such birds would be more subject to disease and internal hemorrhages.

On the other hand, we might have a ration that is too narrow, furnishing more protein. This is a more costly practice because of the higher price of the protein part of the ration. There would be incomplete digestion and probably indigestion of some kind. The kidneys and liver might be overtaxed because they would need to get rid of the excess nitrogen waste. Uric acid poisoning might develop under those conditions.

The question might be asked whether it is possible to overfeed a balanced ration. The answer to that is only one of opinion; but it is probable, if we have a proper mechanical condition of the ration, that the birds would not overfeed on a balanced ration.

DIETARY REQUIREMENTS. There must be a sufficient quantity of feed and a sufficient quantity of the different nutrients to furnish the necessary material for the production of the product. Dietary requirements are available for some of the nutrients. The National Research Council[12] has issued recommended nutrient allowances for poultry. These furnish a good guide for the calculation of rations. However, the final measure will be the results obtained in feeding the rations.

VARIETY. Variety in the ration stimulates the appetite and increases the consumption of food. Of the same or similar breeds or varieties of chickens, the large eaters are the best layers. The birds that consume the most food have more material to make eggs or meat and are likely to lay more or to grow more. In fact, there is a distinct relation between the amount of food consumed and the number of eggs laid, where birds of the same size and variety are compared.

Furthermore, until such time when we know the exact make-up of feeds in respect to all its different parts, and until we know more about the quantitative requirements of poultry, it will be a safer practice not to limit the poultry ration to a very few feeds.

It is desirable that the mash mixture contain five or more ingredients, one being a source of animal protein food. The grain mixture should contain at least two grains.

There is also the possibility that there are still unknown factors in poultry feeding which might be supplied by using a variety of feeds. On the other hand, it is not necessary to go to the other extreme and include fifteen to twenty-five ingredients in the poultry ration. Variety should be reasonable in amount, particularly since it usually can be provided without increasing the cost.

COST AND AVAILABILITY. *Naturally the ration should be modified to fit the local market and farm conditions.* Home-grown grains should be fed just so far as is economical. The particular value of each feed must be considered. For example, it is economy to use the feeds which give profitable results in feeding practice. The value of the feeds should also be computed on the amount of available nutrients, for it is the digestible part that is of use to the bird; it is the digestible portion that becomes available and is made into eggs or flesh. It must be borne in mind, however, that the feed in question may be rendered more or less valuable than indicated by its total digestible nutriment by such other factors as the nature of the feed, the quality of the nutrients, palatability, and fiber content.

FACTORS IN SELECTING FEEDS FOR A RATION

Composition or chemical analysis is not the only thing to be considered in selecting feeds. Other factors must be thought of when one is making a choice.

PALATABILITY. Palatability is an important factor because the birds must consume large amounts of feed. In general, we can say that the more feed the bird consumes, the greater will be the returns in production. This is true both for eggs and for growth The birds soon learn to pick out the feeds that they like and to eat quantities of them. The factor of palatability varies sometimes with the same feed, depending upon its condition. For example, dry oats are not so palatable as germinated oats, sprouted oats, or even just soaked oats. The palatability of individual feeds necessarily has its *effect upon the mixtures* in which they are used. It is not impossible to use, in a mixture, feeds that are unpalatable, but it is not wise to include too large quantities of them in the mixture for fear it might affect the palatability of the mixture.

has little importance during the act of feeding. The hen can distinguish three tastes: sour, salty, and bitter. Wheat-form kernels of grain are preferred, and the larger kernels are usually eaten first. Color does not play an important part. In the case of grits one report has shown a marked preference for light-colored grit (grey, white) as compared with dark-colored ones (blue, green, brown, black).

There is a difference in the palatability of feeds.[14] In practically every case reported, wheat is eaten in the largest amounts and might easily be considered the most palatable feed for poultry. Next in order of palatability are corn, kafir, barley, oats, sunflower seeds, peas, and rye. Rough rice also is very palatable. Buckwheat is not eaten readily. In testing the liking of chicks for certain seeds, Newbiggin and Linton[15] conclude that color, size, dullness or shininess, and chemical composition have no influence upon choice. The grains eaten in largest quantities were those offered in their natural state, that is, neither decorticated nor kibbled. They conclude, therefore, that "natural" foods may be selected in preference to "treated" foods. Hens also seem to prefer the softer kernels of grain.

Of the ground feeds, corn meal is eaten in largest amounts. Wheat standard middlings and wheat bran are next in order. The meat products and milk usually rate good. The flaked buttermilk is eaten more readily than the powdered.[16] Semi-solid buttermilk is usually well liked. Red dog flour, flour middlings, oil meal, blood meal, ground oats, and alfalfa meal are not so palatable. Unpalatable feeds decrease food consumption of a mixture in which they are used unless the amounts used are small and are balanced by the great palatability of such feed as corn meal. Palatability of ground feeds seems to be closely linked with their physical condition. Feeds that are sticky, bulky, or fibrous are not liked. Granular feeds are attractive.

a little more digestible than those in a nonsucculent condition.

The addition of salt to the ration does not affect the digestibility of the feeds. The addition of salt might increase the quantity of feed that is eaten. In that way, we might make available to the birds a larger amount of nutrients by a greater feed consumption.

The grinding of the feed may or may not increase digestibility. It is thought that grinding of the feeds for poultry slightly decreases digestibility. If feed is furnished in the whole form, such as grain, the hen has to grind the feed so that it stays in the digestive tract for a longer period and the digestive juices have more time to act. The amount of feed actually digested probably depends upon the amount of digestive juices, as well as the length of time the feed is exposed to the digestive process. In feeds that are passed rapidly through the digestive tract we find low digestibility. This seems to be true when comparing corn meal with cracked corn. The low digestibility of such feed as wheat middlings, which is slightly laxative, compared with other feeds of similar composition, is probably due to rapid passage through the digestive tract. Any feeds that stay longer in the digestive tract probably have a larger proportion digested.

In general, we might say that cooking feeds lowers the digestibility of protein, but increases the digestibility of starch. As far as we know, the age of the individual or the breed does not affect the actual digestibility of the feed This is also true of the frequency of feeding or the amount of feed that is given.

Assuming that we do not have factors entering in that will cause a more rapid passage of the feed through the digestive tract, digestibility is affected by environmental and external conditions. The flow of the digestive juices is very readily checked by fright and other disturbances.

As a general rule, we can say that the most palatable feeds are also the most digestible, probably because a favorable and vigorous activity is promoted in the digestive tract.

WHOLESOMENESS. Another factor to be considered is the wholesomeness or quality of feeds. In poultry feeding, this quality is quite important. The hen has a very dull taste perception Very little saliva is secreted, and taste organs are not present to the extent that they are in other farm animals. That means that it is quite possible to get substances not entirely wholesome into the body of the hen. One of the first indications that this is happening is loss of appetite and diarrhea. Besides, we have certain other specific conditions. In the case of moldy feed or

litter, we frequently get infection from the aspergillus mold, causing aspergillosis. Very often when we have that condition, we say that the birds are going light. Where birds have access to putrid meat, we might have cases of limber neck or ptomaine poisoning. We must be sure, therefore, that both the feed and the litter are of good quality. It does not pay in poultry feeding to take a chance on either one of them.

EFFECT ON THE QUALITY OF THE PRODUCT. The quality of the product might be affected by the feed. Some feeds do have an effect upon the color, flavor, odor, and other characteristics.

Effect on Color. The origin of the coloring matter in the yolk of the egg and the body of the fowl is the food of the hen.[17] The bulk of the coloring matter in hens' egg yolk is xanthophyll. Xanthophyll is the general term used to describe carotenoids of the formula $C_{40}H_{56}O_2$. The hen has the ability to store xanthophylls but practically no carotene, the cow assimilates carotene but practically no xanthophyll. Chicks raised on rations almost devoid of carotenoids produced hens normal in all respects, except for the lack of yellow color. The yolks of the eggs produced were devoid of pigment. The effect of feeds depends upon the amount of coloring matter present.

Effect on Body Color. In one trial,[18] where white corn meal was substituted for the yellow and no green food was fed, the yellow pigment gradually faded from the shanks, beak, and skin and at the end of 6 weeks the yellow pigment was left only in the toes. Heiman and Tighe[19] reported that increasing the pigment intake of chicks resulted in the proportional increase in the concentration of the pigment in the shanks, that the pigment accumulated in the shanks in an essentially linear proportion in relation to time, and that, where the pigment was withdrawn from the ration, there was a steady loss of pigment from the shanks until they were practically colorless.

Certain common poultry feeding stuffs, such as meat scraps, fish meal, fish oil, and soybean oil meal, contain a factor, or factors, which inhibit the deposition of yellow pigment[20] in the shanks of growing chicks. Bird further showed that with mashes designed to produce rapid pigmentation, a 10-day period was sufficient to change the shanks of Barred Rock X New Hampshire crossbred chicks from cream color to a deep yellow.

Effect on Yolk Color. The yolks of eggs are particularly affected by the coloring matter of the feed.[21] However, Bohren, Thompson, and Carrick[22] have shown that the yolk might obtain

small but persistent amounts of pigment from some other source, probably from body tissues. Green feed and yellow corn are rich in xanthophyll and produce highly colored egg yolks; red corn and hemp seed produce slightly colored yolks; wheat, wheat bran, oats, barley, cottonseed meal, rape seed, meat scrap, and blood meal have little effect on the color of the yolk. Large quantities of the coloring matter found in egg yolk are found in grass and also nearly all kinds of yellow flowers.[23]

The feeding of ground, dried, ripe, pimiento peppers[24] produced eggs that were orange colored, as compared with light lemon-yellow eggs for the control pen. Rations containing pimientos also imparted a rich yellow color to the shanks, skin, and fat, the amount of color depending upon the amount of pimiento fed. Experiments carried out in Hungary[25] proved that the feeding of paprika caused a much darker color in the yolk, the color being four times deeper than at first, within 3 weeks' time.

In a study of seasonal variations in yolk color, Parker concludes that the most important factor in yolk color is the amount of greens actually eaten by the birds.[26] Birds having an unlimited supply of green feed produced eggs with dark-colored yolks. Kale at the rate of 5 pounds per 100 birds a day or alfalfa leaves to the amount of 5 per cent of the mash gave yolks of a desirable color.

Because alfalfa meal is known to be a valuable ingredient in poultry rations, levels that are too high have sometimes been used. There is a close association between the amount of alfalfa fed and the depth of yolk color. However, no unfavorable reactions are experienced where approximately 5 per cent of alfalfa meal is used in the mash.

Carver and Heiman[26] found that Argentine corn (flint) produced eggs with deeper-colored yolks than domestic corn (dent) The groups fed higher proportions of pigment-bearing foods produced eggs with deeper-colored yolks, but the amount of pigmentation deposited in the egg yolks was not proportionate to the amount of pigment in the ration. The color changes induced by the rations fed began to take effect after the fourth or fifth day of feeding. It took about 13 days to reach maximum pigmentation. When pigmented foods were withdrawn, it required about 26 days for the pigmentation to become stabilized. An index of 12 – 13 is satisfactory. This index will be produced by 20–30 per cent of Argentine corn, 8 per cent of dehydrated alfalfa, or 4 per cent of dehydrated alfalfa plus 10 per cent of Argentine corn.

Frequently discoloration of new-laid eggs is reported, due to

the consumption of certain materials. Olive-colored egg yolks[27] are reported to be produced by shepherd's purse and penny cress, weeds belonging to the mustard family. Thompson of the Oklahoma Station has also reported the development of eggs with orange-colored yolks from a ration containing 12 per cent of kafir smut. The feeding of cottonseed meal frequently causes the appearance of cottonseed spots on the yolks of the eggs or olive yolks.[28] (See also Chap. 7.)

Olsen[29] reported production of eggs with olive-colored yolks from diets containing whole acorns, ground acorns, ground acorn meats, or ground acorn hulls. Temperton[27] reports the production of eggs with greenish-brown yolks only when the acorns were germinated.

Peterson[30] and coworkers found that hens fed an all-mash ration containing 10 per cent of lobster shell produced highly colored orange-red yolks, which they attributed to the effect of the tetraoxycarotenoid astacin present in lobster shells.

It is possible to color artificially the yolks of eggs and body fat by means of dyes.[31] Rogers reports that fowls fed Sudan III produce eggs with yolks of a bright red color. The forming of the coloring matter in the yolk takes place in the shape of concentric rings or layers. Rhodamine Red colors the yolk slightly. Auramine Yellow and Saffranine Red act in much the same way as the Rhodamine Red. In testing a large number of dyes, Denton states that the water-soluble dyes were not deposited in any part of the egg, while seven of the alcohol-soluble dyes were deposited in the yolk, producing slight green, green, pink, magenta, blue, and red yolks. Hexyl blue dye was withdrawn from the body fat depots and deposited in the yolk. The Rhodamine Red colors the albumen strongly, giving a pink color. It also colors the body muscles, the feathers, which are being grown when the dye is in the blood, and the shell and albumen of the egg.

Effect on Feather Color. The yellow and red lipochrome colors originate in the food. If food not containing these colors is given, the feathers[32] fade completely. Dyes other than carotenoids are not absorbed by the feathers. Carotene causes a yellow color in the feathers, and paprika-containing food causes an orange color.

Effect on Eye Color.[33] Feed has a significant effect on eye color. A ration lacking the yellow pigments prevents the deposition of such pigments in the iris of Single Comb White Leghorns. Since both the diet and the vascular system of the iris play an important role in determining eye color, caution must be exer-

cised in the culling of Single Comb White Leghorns on the basis of eye color alone.

Effect on Taste. In general, feed has little effect on taste.[34] The hen puts the feeds that it consumes through an effective refining process. However, certain feeds have been reported as affecting the flavor of the egg or flesh. Certain feeds, if given in large quantities, might affect the flavor to a slight extent. For example, rape, turnips, cabbage, and fish have been reported as affecting flavor. The feeding of fresh onions very quickly develops a distinct taste in the eggs. The Oklahoma Station[35] reports that hens fed 5 grams of garlic pod daily produced in 5 days egg yolks with a distinct flavor. The flavor was not found in the albumen until after 30 days of garlic feeding. At no time was an odor found in any part of the egg, either raw or cooked. Feeding 5 grams of dried onions produced no changes in flavor, odor, or appearance.

Cod liver oil, as usually fed, has not been reported as affecting the flavor of the egg. The feeding of two number three capsules[36] of cod liver oil daily, however, produced a very distinct fishy flavor in the yolk in 30 days, but no flavor in the albumen. The flavor was found in eggs after 6 months of storage.

Off-flavor in the meat of chicks and turkeys has been reported.[36] This has been traced to the feeding of cod liver oil or large amounts of fish meal, especially meals with a high fat content. Fish oil and fish meal should be discontinued in the ration fed market turkeys at least 8 weeks before they are dressed. Carrick and Hauge report that feeding 2 per cent of cod liver oil imparted a "fishy" taste to the flesh of chickens and that it took about 2 weeks for them to lose the "fishy" taste; that the taste on this amount was not apparent when the chicken was warm but seemed to be intensified when eaten cold; that the degree of "fishy" flavor was affected by the method of cooking; and that 4 per cent of oil gave a decided flavor to the flesh. Apparently, the amount of oil is a factor. One per cent or less of oil in the ration usually does not impart any flavor; but to eliminate any possible effect, the recommendation is frequently made, especially with broilers, to eliminate the oil for a week or 10 days before selling.

Certain feeding practices have been followed to affect the flavor of the flesh. For example, the feeding of celery is thought to impart a flavor. The characteristic gamey flavor in wild birds is produced to some extent by the food which the birds are eating

In reporting the effect of feeds upon the quality of meat in tur-

keys, North[37] reported a more intense flavor and aroma of oat-fed roasted birds, as compared with those fed corn, wheat, barley, or rye. Corn-fed birds were more tender after roasting. Dry skimmilk produced a less intense aroma in the breast meat of the roasted birds. The least desirable flavor was found in birds which had been fed cottonseed meal. When a feed, 60 per cent of the protein concentrate of which was cottonseed meal, was fed, the juice was found to have a poorer quality than when the other supplements were fed (soybean oil meal and corn gluten meal). Corn gluten meal produced juice of a better quality than any of the other concentrates.

Payne[27] reports that eggs of an olive color, caused by the birds feeding on shepherd's purse, have a strong flavor. The Kansas Station[38] also reports a trend for dark-colored yolks to have a slightly higher flavor score (more objectionable), although the differences probably would not be readily detected by the average consumer.

Effect on Body Composition. The nature of the carcass fat[39] has been shown to be affected by the kind of dietary fat.

Effect on Egg Size. Many factors affect egg weight in the domestic fowl, such as age, sexual maturity, body weight, time of day the egg is laid, position in the clutch, and breeding, as well as deficiencies in the ration.[40] Feeding has a very definite influence on the size of eggs. Idaho[41] indicates that the highest percentage of small eggs is obtained where no protein feed was given. Results in Northern Ireland[42] also indicate, for a period of 2 years, the production of 44 per cent of second-grade eggs on a ration of cereals only, as compared with 23 to 26 per cent on rations having protein concentrate additions. The feeding of grain only showed lower egg weight in trials at Oklahoma[43] and 12 per cent reduction in egg weight at West Virginia.[44] Eggs produced on low-protein rations are smaller than those produced on rations of higher protein content.[45]

The egg was larger when certain animal protein feeds were added to the ration.[41, 46, 47] Idaho reported the following egg size when comparing pea meal and sour skimmilk. It has also been reported by several stations that milk, especially sour skimmilk,

Egg Size	Percentage of Eggs Pea Meal	Sour Skimmilk
Up to 22 oz. per dozen	38	21
22-24	43	37
24-28	19	42

was superior to other animal protein concentrates in the effect it had on the weight of the egg produced.[41, 43-50]

The proportion of second-grade eggs, as reported by Robertson and Baskett,[42] decreased from 44 per cent to 27 per cent by the addition of minerals to a basal ration made up of cereals. They conclude that the evidence is strong that the weight of the egg is a function of the mineral portion of the ration. Kentucky[50] reports that in the absence of a calcium carbonate supplement the eggs became smaller.

With inadequate amounts of vitamin D, the average egg weight was materially reduced.[47, 51] Graham[51] reports that adding cod liver oil to the ration of laying pullets brought a slight increase in egg weight from February to July.

Parkhurst[47] also reports that green feed proved of value in increasing egg size. Smith[52] states that germinated oats caused a consistent increase in the average weight of eggs.

A well-balanced ration has been reported to give larger eggs and less variability than a poorly balanced ration.[48, 53] Parkhurst[48] and Atwood and Clark[54] indicate that rations which tend to increase or decrease production tend to have a similar influence on egg weight. Atwood and Clark also report that a physiological disturbance produced by the drug kamala caused a decrease in production, with an attendant decrease in egg weight. The altered physiological condition of the birds caused a fluctuation in the weight of the eggs, owing to materially decreased secretion of albumen. It was also observed at Cornell that egg weight was lowered during an attack of infectious laryngotracheitis.

Effect on Eggshells. The lack of sufficient amounts of vitamin D will decrease the amount of lime in the shell, decrease the percentage of eggshell, and produce thin and soft-shelled eggs.[51, 55-58]

Morgan and coworkers[59] report that feeding cod liver oil to pullets on range, under climatic conditions of South Carolina, tends to increase the breaking strength of shells of eggs, the percentage of shell, and the percentage of calcium carbonate in the shells, but the increase is slight.

A lack of an adequate calcium supply, in chemical combination available to the hen for the manufacture of eggshell, will tend to produce smaller and thin-shelled eggs.[50, 57, 60]

Experiments reported from Cornell[61] and Arkansas[62] show that the breaking strength of eggs is related to the quantity of manganese in the diet. The ash content of the eggshells was

also found to increase with an increase in the manganese content of the diet.

Effect on Storage Quality of Eggs. The feeding of cottonseed meal, even when showing no discoloration of yolk or white when newly laid, caused eggs in cold storage to show discolored yolks and in some cases discolored whites. Eggs from hens fed cottonseed meal, crude cottonseed oil, partially refined cottonseed oil, and ether extract of cottonseed oil deteriorate in storage (see also Chap. 7).

The California Station[63] reports that in every case the fat of those plants belonging to the family of which cottonseed is a member gave a positive reaction to the Halphen test. Cheeseweed and California windbreak seeds were included in the diet of laying birds, and the eggs reacted to the test. They developed "pink white" on storage as did eggs from birds fed cottonseed. However, the deterioration of eggs resulting from cottonseed meal is caused by two distinct substances. Gossypol gives the yolk an olive-green color and a gelatinous consistency; the Halphen substance causes an abnormal enlargement of the yolk and a reddish color of the yolk and albumen to develop in storage.

Swensen, Fieger, and Upp[64] report that the olive-colored yolks are due to chemical combination of gossypol with ferric iron released from the egg protein of the yolk during storage. Addition of soluble ferric salts to the ration prevented the formation of olive yolks.

Effect on Interior Egg Quality. As far as the albumen of the egg is concerned, in general, feeds have not influenced interior egg quality[65, 66] as much as other factors, such as breeding and handling.

Illinois[67] reports that the feeding of high proportions of the common grains, corn, wheat, or oats, did not influence the percentage of thick white enough to result in eggs of distinctly inferior quality, but that there was some indication that the proportion of thick white may be influenced by the ration fed. The further addition of mineral supplements or a decided increase in the potential alkalinity of the ration had no noticeable effect on the percentage of thick white.

A report from Wyoming[68] indicates that hens fed rye produced eggs with a lower ratio of thick white to thin white and a lower yolk index, causing the eggs to appear aged in spite of their being strictly fresh. Barley also showed a slight tendency to produce a lower ratio of thick white.

The New Mexico Station[69] showed that the index of quality of

eggs produced by hens receiving green feed was less than that of eggs from hens receiving no green feed, and that the eggs produced on green feed depreciated in quality more rapidly with increased age. The Oklahoma Station[35] indicated that in all instances eggs from the pens receiving green feed had a thin and more liquid albumen than eggs from pens receiving no green feed.

In general, variation in the percentage of thick albumen or other characteristics of interior quality was not definitely attributed to the amount or kind of protein fed.[65, 70] However, Heiman, Carver, and St. John[70] found that the level of protein apparently affected albumen quality, in that they obtained a significant difference in albumen index between hens fed 12 to 13 per cent protein from plant sources only and those fed higher percentages of protein from both plant and animal sources.

Experiments at Cornell indicated that such nutritive factors as proteins, carbohydrates, fats, minerals, vitamins, and water had little if any effect upon the percentage of thick albumen. The Colorado[71] Station reported that egg albumen quality does not appear to be related to the content of vitamin A, carotene, nicotinic acid, folic acid, and apparent pyridoxine

EFFECT ON VITAMIN CONTENT OF EGGS. The vitamin content of the feed has an effect upon the vitamin content of the egg. Experiments at the Ohio Station[72] indicate that access to bluegrass or feeding 2 per cent of cod liver oil increased the vitamin A potency of the egg yolk five times. Alfalfa hay also tended to increase the vitamin A content

The vitamin D[55, 72, 73] content of the eggs is also influenced by feeding or exposure to ultraviolet rays Hart and associates report the antirachitic potency of egg yolks from irradiated hens as being about ten times that of yolks from nonirradiated hens. The Ohio Station indicates that egg yolks from birds fed cod liver oil or irradiated ergosterol, or exposed to sunlight, had five to ten times as much vitamin D as egg yolks from birds confined behind window glass Branion, Drake, and Tisdall increased the number of Steenbock units of vitamin D from 4 to 30 by adding 2 per cent of cod liver oil and as high as 18,000 units by the addition of highly potent viosterol. Kentucky reports that the yolks of eggs produced in the spring and stored until fall and winter were found to have a higher content of vitamin D than the yolks of eggs produced in the fall and winter under like conditions. Work done at Cornell would indicate that egg yolks produced by hens receiving direct sunlight were more potent in vi-

tamin D than egg yolks from hens receiving cod liver oil or ultraviolet light.

The content of the water soluble vitamins of eggs has been influenced by the ration.[74] The Ohio Station reported that attempts to increase the pantothenic acid content of eggs by feeding hens feeds high in this factor have given negative results. On the other hand, Bauernfeind and Norris showed that hens receiving a heated experimental diet deposited less pantothenic acid in their eggs than hens fed a normal diet. Snell and coworkers also reported that eggs from hens maintained on a diet low in pantothenic acid showed markedly lowered pantothenic acid content, and that within the limits of the experiment the pantothenic acid content of the egg is directly proportional to that of the diet. Gillis, Norris, and Heuser showed that the pantothenic acid content of the egg varied directly with the content of the diet and reached levels much higher than present in the blood.

Norris and Bauernfeind report the average riboflavin content of fresh eggs produced by hens fed egg mashes to be approximately 2.07 micrograms per gram of edible substances (105 micrograms per egg) and that of the eggs produced by hens fed breeder mashes to be 2.48 micrograms per gram (125 micrograms per egg). The lowest riboflavin value obtained experimentally was approximately 0.82 microgram per gram of edible substance (40 micrograms per egg), and the highest value was 3.26 micrograms per gram (165 micrograms per egg). In these studies it was found that the riboflavin content of fresh eggs could be increased approximately 1.9 micrograms per gram above that of the eggs laid by hens fed the basal diet (the riboflavin content of the eggs produced on the basal diet was 0.82 microgram per gram in one experiment and 1.40 micrograms per gram in two other experiments). The time required to attain maximum riboflavin storage in eggs and that required to deplete to the basal levels varied from about 2 to 4 weeks. In general, the riboflavin content of egg white changed more rapidly than that of egg yolk.

Experiments at Cornell showed that the vitamin B_{12} content of the egg is influenced by the amount of this vitamin in the diet and that the vitamin B_{12} in the diet is related to hatchability.

EFFECT ON MINERAL CONTENT OF THE EGG. Experiments[75] show that both the iron and copper content of eggs can be affected by feeding.

It has also been shown that the iodine content of eggs is af-

fected by the iodine content of the ration.[76] An increase as great as 450 times the original content has been reported by the feeding of iodine preparations.

Experiments conducted at Cornell[61] and Kentucky[77] indicate that the manganese content of eggs from a low-manganese group was smaller than from high-manganese groups and that the breaking strength of eggs increases as the quantity of manganese in the diet increases.

EFFECT ON COMPOSITION OF THE EGG. As far as total composition is concerned, there is very little effect of the feeds on the chemical composition of the egg. The composition of the various parts of the egg (white, yolk, shell) varies greatly, but these variations are independent of the system of feeding.[78] In comparing the composition of eggs produced on a nitrogenous as compared with a carbonaceous ration, one finds very little difference in the protein, fat, and water content of the yolk. The white of the egg might show slightly more protein on the nitrogenous diet. This might be true because the white of the egg is a secretion. The Wisconsin Station[55] reported that irradiation with ultraviolet light did not affect the calcium and phosphorus content of the whites and yolks. Kentucky workers[79] reported that, as long as the economy of the hens permitted the formation of an eggshell, the contents of the egg remained reasonably constant, thereby permitting an average supply of calcium, magnesium, and phosphorus for the proper development of the embryo of the chick, and that the presence or absence of oystershell in the diet had no appreciable effect upon the percentages of protein and of calcium in the white and yolk. The hen endeavors to keep a steady chemical condition of her egg and will do so even at the expense of her body

U.S.D.A. workers[80] indicated some effects of diet upon composition, although the effects were usually small. The yolks appeared to be more readily affected than the whites The most consistent differences were observed in the percentage of protein in the dry matter of the yolk of eggs The various N or protein determinations showed little or no difference McFarlane, Fulmer, and Jukes[81] found no significant difference in the composition of the proteins of eggs of poor hatchability, so far as the total nitrogen, total amino-nitrogen, tyrosine, tryptophan, and cystine content were concerned, as compared to the composition of the proteins of eggs of high hatchability. There was no clear evidence that the diet of the hen had any influence on these values.

Pollard and Carr[82] report great differences in the proteins of eggs from pigeons fed different cereals, especially wheat, rye, oats, and corn, which contained high tryptophan.

Dietary fat has been reported as having some effect upon type of egg fat[83] of the hen.

EFFECT ON OTHER EGG CHARACTERISTICS. Atwood and Weakley[84] report that their results would indicate that the presence of a considerable amount of animal protein in the ration for laying hens tends to weaken the vitelline membrane. Ovarian hemorrhages, resulting in blood and meat spots[85] in eggs, have been reported as being reduced substantially by allowing the hens thus affected access to range or by feeding them Cerogras. Anderson[86] indicates that evidence available strongly suggests that diet may influence to a very considerable degree the bacterial flora and the normal bacteriostatic properties of the eggs produced.

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CHAPTER 10

FEEDING SYSTEMS AND PRACTICES

Considerable variation in feeding systems and practices is met with in recommendations for and actual feeding of poultry. Methods of feeding have long been given serious attention by poultrymen. Still there is no standard uniform method of feeding universally practiced by poultrymen. This lack of uniformity, no doubt, is an indication that the make-up of the ration and food intake are more important than the method of feeding. It has been pointed out repeatedly that food consumption and egg production follow each other closely. Hewitt[1] reports a very close relationship between egg yields and food consumption in 20 years of poultry feeding experiments.

Several types of rations or systems of feeding have been evolved and used. They range from the mashless, or all-grain, rations to the grainless, or all-mash, rations, with the combination or grain-mash rations ranging between the two extremes. Also various modifications or combinations of these systems are used. Each system has its advantages and disadvantages.

WHOLE-GRAIN METHOD

This was the original method of feeding poultry. When the flocks were small and the hens ranged over the farm, they picked up seeds and grains. When necessary to supplement this feeding, extra grain was fed in the barnyard. Later, when large numbers of birds were kept and were more closely confined, the grain was supplemented with some animal protein feed to take the place of bugs and worms. The first practice was to feed beef scrap dry in hoppers. The results[2-4] of early experiments were not entirely satisfactory in all cases, and this practice was superseded by combination rations.

Later experiments[5] have reported as good production and in some cases better production from feeding grain plus an abundant supply of liquid skimmilk or condensed buttermilk. It is possible to feed grains in various combinations. In the main, it

is better not to limit the grain to one cereal. Average grain consumption was 73 pounds a year per hen and average milk consumption 13 gallons in the Kentucky trials. Excellent and economical egg production was obtained at the Washington Station by feeding unground grain mixtures (wheat and oats; wheat, barley, and oats; wheat, corn, and oats), supplemented with sour skimmilk. *An average yearly production of approximately 250 eggs per pullet was obtained from all the pens in one series.* About 55 pounds of dry feed and 185 pounds of milk per year were consumed by each Leghorn pullet.

Because of restricted milling, making wheat by-products unavailable, and because of transport difficulties, many Australian poultry farmers during World War II resorted to the feeding of soaked grain.[1] Wheat, being most plentiful, was the common choice of grain. Highly satisfactory results were obtained by feeding whole grain supplemented by meat meal.

ALL GRAIN FOR CHICKS. The feeding of all grain and beef scrap to chicks at Cornell[6] showed variable results, depending upon meat intake and food consumption.

In recent years the feeding of grain to chicks for the first 2 or 3 days has been recommended in order to prevent "pasting up." Peterson[7] reported that feeding chicks cracked grains as the only feed for the first 2 days had a protective value against "pasting up," where the first week brooder temperature was above or below 98° F. However, at the end of 3 weeks there was no significant difference in the average net gain, number of chicks "pasted up," or average feed consumption for either system of feeding In groups brooded at low temperatures, the mortality was somewhat less where grain was given as the only feed for the first 2 days, as compared with those fed the all-mash ration.

POINTERS ON FEEDING ALL GRAIN. In connection with using home-grown laying rations, Carver[8] suggested that no one should feed a whole-grain plus milk ration without a regular daily supply of skimmilk or buttermilk. The whole grain should be limited to 16 pounds, and the milk supply should be at least 40 pounds per day per 100 birds.

MERITS OF THE ALL-GRAIN METHOD. Some of the advantages of the whole-grain system of feeding are:

1. Making possible easy use of large amounts of home-grown grains.
2. Saving expense and trouble of grinding.
3. Easy determination of quality of ingredients.

grain and containing no ground grain. More food was eaten when the ground grain was fed than when the whole grain was fed, and the chicks made more rapid gains.

In 1903 Stewart and Atwood[2] concluded that "with young White Leghorn fowls a large proportion, if not all, of the ration can be composed of ground food without diminishing either the egg production, decreasing the hatchability of the eggs, or injuring the health of the fowls."

Satisfactory gains were secured at Cornell[6] with chicks up to 6 and 8 weeks on rations that were fed in the ground form.

Wisconsin,[11] in 1924, reported the successful rearing of 6,000 birds on an all-mash ration. This ration consisted of 80 parts of ground yellow corn, 20 parts of wheat middlings, 5 parts of raw bone, 5 parts of pearl grits, and 1 part of salt. Skimmed milk was given ad libitum as a drink and no water. Since then there has been a renewed interest in all-mash feeding.

The all-mash system of feeding ignores the exercise theory of feeding scratch grain. It is believed, by its advocates, that the birds secure enough exercise in the ordinary activity of feeding and walking about the pen.

ALL MASH FOR HENS. Buss of the Ohio Experiment Station[4] reported no difference in the number of eggs produced per hen in 2 years from hens receiving all-mash and hens receiving grain-mash rations. Since that time many experiments have reported practically no difference between the two methods[12] from the standpoint of amount of feed, number of eggs, size of eggs, weight of hens, mortality, health, fertility, and hatchability. A few trials indicated more uniform results with the all-mash ration. In some instances the grinding of feeds for the all-mash ration made it uneconomical.

Many experiments[13] report better results with rations containing both mash and scratch grain as compared with all-mash rations. Some trials report a tendency for birds to gain more weight on grain-mash rations. Also yolks were more variable in color in the grain-mash lots than in the all-mash lots.

In experiments conducted at Cornell, the difference in egg production, especially for pullets, has usually been in favor of the grain-mash rations, as shown in Table 16.

The Western Washington Station[14] concluded that the all-mash ration proved satisfactory where skimmilk was available as a drink.

During World War II, because of the scarcity of grain, British poultry producers were forced to feed an all-mash diet. The

TABLE 16. EGG PRODUCTION ON ALL-MASH AND GRAIN-MASH RATIONS AT CORNELL

Year	All Mash	Grain and Mash
	Pullets	
1927	173 ± 5.4	188 ± 3.7
1928	195 ± 4.3	205 ± 4.7
	179 ± 5.3	194 ± 4.5
	189 ± 4.7	200 ± 6.2
1929	203 ± 6.2	218 ± 5.5
1930	194 ± 5.6	226 ± 4.6
1931	210 ± 3.8	220 ± 5.7
Av.	191.6 ± 1.99	207.4 ± 1.84
	Hens	
1930	170 ± 3.9	184 ± 3.4
1931	176 ± 2.5	175 ± 4.5

results were sufficiently favorable to raise the question as to whether they would return to grain feeding when the war was over. Some authorities think not because they believe that feeding mash is cheaper.

High energy all-mash rations have proven very satisfactory. The development of mechanical feeders[15] has also favored the all-mash ration by raising total feed consumption.

ALL MASH FOR CHICKS. This method of feeding has proved very popular for chick feeding. The Ohio Experiment Station[12, 16] has used it successfully for many years. A Colorado report showed that the all-mash ration gave greater uniformity of growth, less death loss, and was more economical. The South Dakota Station[17] indicated all mash was satisfactory for chicks and simplified feeding. Feed consumption was reported less in the all-mash lot. However, after 6 to 8 weeks the scratch and mash ration was considered more successful. Reports from England[18] indicate no difference in weight at 20 weeks, cost of feeding, and quality of pullets produced on the all-mash as compared with the grain-mash system. Experience at Cornell also shows this condition. Other experiment stations indicate the all-mash method to be preferable for chicks.

ALL MASH FOR FATTENING. A review of fattening practices indicates almost universal agreement in using ground feeds almost exclusively for this purpose.

ADVANTAGES OF THE ALL-MASH SYSTEM. Some of the favorable points of this system might be listed as follows:

1. More sanitary. The feed does not have a chance to become

contaminated by damp and filthy litter. (This would also apply where grain is hopper-fed.)

2. Simplicity. Fewer mixtures need be considered, and routine is simplified.

3. Less skill required in feeding. Superior results will probably be secured in the hands of the unskilled feeder.

4. Less labor required.

5. No change of feed. A mash mixture is fed throughout the period.

6. A definite ration. There is no guesswork or confusion about what proportion of scratch grain to feed.

7. More uniform food intake. Each individual gets all the ingredients of the ration in the same proportion. This advantage makes the system particularly adaptable to experimental work.

8. Uniformity of growth.

9. Uniformity of yolk color.

10. Adaptable to mechanical feeders.

DISADVANTAGES OF THE ALL-MASH SYSTEM.

1. Less flexible. Proportions of grain to mash cannot be varied to meet changing needs of the birds. This might necessitate frequent changing of the all-mash mixture or supplementation.

2. More and better feeding appliances needed.

3. Ground grains are slightly more expensive.

4. It is more difficult to teach chicks to eat mash.

ALL-MASH FEEDING PRACTICE. The all-mash rations usually contain a larger amount of cereals and one-half the amount of protein concentrates that are used in mashes to be fed with grain. The mixture should not be too fine; otherwise food consumption will be discouraged. Feeding fresh mash at least once a day (prefereably in the afternoon) will also encourage consumption. Sufficient hopper space must be furnished, and the hopper must be of the type that will not clog. The National Institute of Poultry Husbandry in England gives the following specifications for feeding space when all-mash rations are used:

1–4 weeks	6 feet per 100
4–10 weeks	12–14 feet per 100
10–20 weeks	16–20 feet per 100
Mature	24 feet per 100

With all-mash mixtures there is less stirring over of the lit-

ter. The litter is likely to become matted and wet. In this respect, proper sanitation is more difficult in the all-mash pens and necessitates more frequent cleaning.

If the mature birds are to be fed an all-mash ration, it is best to feed an all-mash ration to the chicks.

In making up all-mash rations, one must be sure that they are complete and that the mixture is one that can be eaten in sufficient quantity. In some instances, difficulty was encountered in developing all-mash rations. These rations were adapted from combination laying mashes in common use, with the result that they were too bulky because of a high content of fiber-rich feeds. It is not possible for a hen to eat as much of such a mash during a day as of a heavier, more concentrated mash. Bulkiness in a mash is not a serious fault, however, when a mash possessing this characteristic is fed along with a scratch mixture consisting mainly of cracked corn and wheat. But when a bulky mash is fed as an all-mash ration and it is not possible to get satisfactory results, the tendency is to blame the all-mash system of feeding. This blame, however, is unwarranted. The blame must be laid to the bulky nature of the mash, which makes it impossible for the birds to eat as much feed as those fed a ration consisting of both scratch and mash mixtures. In other words, the all-mash ration was incomplete. Its nutritive value was low because of too high a content of fiber-rich feeds. High energy mashes have overcome this difficulty.

PELLETS OR CUBED FEEDS

This system of feeding is really a modification or adaptation of the all-mash system. It consists of mechanically pressing the mash into hard dry pellets or "artificial grains."

Dairy farmers and feeders of other forms of livestock in Europe have long been accustomed to feed balanced rations in the form of nuts or cubes. The idea has also been applied to a considerable extent to poultry feeding.

PELLETS FOR HENS. The National Institute of Poultry Husbandry[19] in England, in one report, indicates that pellets have given satisfactory results and compare favorably with all-mash feeding. In another trial, one of the B vitamins was destroyed in the pelleting process, which adversely affected hatchability of the eggs and growth of the chicks, with loss of chicks showing symptoms of vitamin B deficiency.

At Cornell a pen of pullets fed pellets laid 175 eggs, whereas

the all-mash pen laid 189 eggs per bird. Other reports[20] show favorable results for pellets when fed to hens. Some observations on pellet feed were better maintenance of body weight and greater tendency toward cannibalism. A report from Germany[21] indicates that hens prefer grain to pellets, that better production was secured by feeding the birds mash and grain, and that the feeding of pellets was not economical. In these experiments it was clearly shown that the birds distinguished between differently shaped pellets and nuts.

Pelleting high fiber feeds[22] such as oat hulls, alfalfa meal, and feed screenings increased the effectiveness of these feeds as compared with them in non-pelleted form.

PELLETS FOR YOUNG STOCK.[23] From the point of view of growth and food consumption per unit of gain, a ration in pellet form has been reported as good or superior to one supplied as dry mash. The mash-fed chicks usually consume more feed as well as feed per unit of gain than the pellet-fed chicks. The pellet-fed chicks usually gain more and consume more water. A greater incidence and severity of feather picking is likely to occur with pellet-fed birds, especially when the chicks are confined. At Cornell pelleting a medium-energy chick ration improved the same so as to make it comparable to a high-energy ration. The increase in growth, due to pelleting, is more marked as the fiber in the ration is increased.

In comparing pellets versus mash for table duck production, Tallent[24] secured slightly greater weights for the ducklings fed the mash. The ducklings did not eat the dry pellets readily till they were 5 weeks old. On the other hand, McMurray[25] observed no difficulty in this respect and obtained better growth with pellets. At Cornell[26] feeding pellets to ducklings resulted in best growth when compared with other methods of feeding Serfontein[27] found no difference in weight between lots receiving whole dry pellets and those being fed ground pellets in a wet form. Feeding the dry whole pellets resulted in less feed wastage, saved labor and hopper space, and was more hygienic

Pellets have also been fed satisfactorily to turkeys [28] There seems to be some advantage in offering a choice of coarse and fine particles at the start. Pelleting enables a satisfactory use of higher levels of dehydrated green feeds.

ADVANTAGES OF PELLET FEEDING The advocates of this system of feeding advance the following points in its favor:

1. No waste. There is little billing of feed out of the hoppers, and when knocked out of the feed hopper the pellets are often picked up again.

2. No clogging of hoppers.
3. No selection of ingredients.
4. Every kernel is balanced.
5. Less storage space required, as the bulk of the feed is reduced by compression.
6. Greater convenience in feeding.
7. More sanitary, especially when fed in hoppers.
8. More palatable. Hens naturally prefer a granular feed. This may mean increased consumption.
9. Time and labor saved in feeding.
10. Feeding simplified. (Can be fed like grain or mash or both.)
11. Less feed required.
12. Less feeding space required.

DISADVANTAGES OF PELLET FEEDING.

1. Cost of manufacture.
2. Less flexibility.
3. Camouflaging of the ingredients.
4. More vices. Owing to less exercise and the fact that a bird can fill up quickly on pellets, there may be more toe picking, cannibalism, and feather pulling.
5. Crumbling of pellets.
6. Vitamin content of ration may be affected. This is true if the feeds are subjected to high temperatures.

Pellets are produced in varying sizes to meet the needs of the size of the birds. To adults usually the pellets $1/8$ to $3/16$ inch in diameter are fed. They may be fed as an all-in-one ration, may be used in connection with scratch feed, or may be used as a supplement to either. They can be fed in combination with an all-mash ration without upsetting the balance. They may be fed either in hoppers or in the litter for extra exercise. They can be used as a supplement in place of wet-mash feeding. Sometimes difficulty is experienced in getting sufficient pellet consumption during the short days of winter. In that case it may be necessary to litter-feed some pellets and even moisten and feed them.

The feeding of pellets, either alone or in connection with mash, has proved satisfactory for birds kept in batteries or cages.

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granular form by means of tremendous pressure. Except for form, they are similar in many respects to pellets. The advantages indicated for pellets also, in the main, hold for kernels. Some improvement in growth rate has been reported from the feeding of granules to chicks.[29]

FREE-CHOICE OR CAFETERIA SYSTEM

In this method of feeding the bird is given a chance to select its own feeds since the individual feeds are made available separately. This system is advocated by some on the grounds that individuality is the basic biological factor. The individual needs of the hen vary, depending upon its weight, production, and condition. It is believed by some feeders that the hen will balance her own ration if given an opportunity, owing to an instinctive ability of animals to choose the proper food constituents when given free choice of diet. This ability to balance their ration has been shown to a surprising extent by some farm animals. Of man it has been stated that, in ordinary life, appetite is a fairly reliable guide to the quantity of fuel food required (the more work the larger the appetite), but it is no guide to the right kind of food. Likes and dislikes are not a reliable guide, especially among an abundance of artificial foods. As a result of a study of individuality in the nutritive instincts and of the causes and effects of variations in the selection of food, Dove[30] states that the expressions of the nutritive instincts vary from individual to individual. Some individuals appear wise and others unwise (less wise) in their choice of food. This fact contraindicates the group technique of free-choice feeding.

In discussing how animals choose their food, Harris[31] states that the power of picking out the particular food is possible only under certain quite special circumstances and by no means always. Animals chose the right food if it "made them feel better" almost immediately after they had eaten it, and they could then associate their rapid recovery with the particular food that they had just eaten. If a "reward" follows the eating of a particular food and if there is something about the smell or taste or looks of the food by which the animal is able to recognize the food again and distinguish it from other foods, he will learn to take it quite easily. (This is a matter of experience and not instinct.) Rats may actually die from protein starvation when offered pure protein, fats, etc., because of delayed effect. Reactions to vitamin B and salt are immediate. The effect of cod liver oil is not immediate.

Jukes[32] showed that the choice of food by chicks was the same when the sugar content was varied, even when the amount of sugar was as high as 20 per cent. Marked preference was shown when the salt content was above 2 per cent, the quinine content above 0.03 per cent, or the citric acid above 2 per cent. Tests to determine whether the taste factor (sugar content) was important in the chicks' choice of food in vitamin G and A deficient diets were negative.

Price[33] concluded that chicks have the ability to select the proper feeds. This ability was shown in their selection of butters high in a factor that increased the blood calcium and phosphorus and prolonged life. When given free choice of samples of butter that could not be distinguished by man, the chicks selected and ate two and one-half times as much of the butter containing a large amount of the active factor as they did of the butter containing a small amount of it.

It has been reported by workers in Germany[34] that the appetite of poultry is not only dependent on physiologic conditions but that it is also strongly influenced psychologically by various outside influences. The manner in which food is given influences consumption. More is eaten from large than from small piles. The approach of one or more hungry hens is of influence. More is eaten when the birds are fed together than when they are fed separately. A hen that had to watch two other birds eat first took 42 per cent more food than normally. More food is eaten from a soft surface than from a hard surface. Large grains are preferred to small. Less is eaten in semi-darkness, in green light, and in blue light than in red or yellow light. Chicks picked at all kinds of objects which were clearly distinguishable from the subsoil or background if the objects could be taken in the beak. However, they swallowed only that which was really nutritive.

The hen can distinguish three tastes—salt, sour, and bitter. However, the taste sense is not important since chickens select feed more by shape, size, color, and surface condition.[35]

De Bocarmé[36] observed that poultry eat a certain amount of such substances as dry leaves, beech twigs, pebbles, glass, splinters, but that these are consumed in an attempt to furnish the necessary mineral salts. Therefore, if the feed is completely adequate, the animals will automatically cease to devour substances other than feed.

Food consumption is also influenced by the condition of the feed. Alder[37] reported that coarse mashes are more desirable

for laying hens than finely ground mashes and resulted in higher egg production and lower mortality.

It has been shown[38] that *there is variation in the kinds and proportions of the ingredients that individuals will select.* They also vary as regards the efficiency with which they utilize food. The amounts of the different foods varied with the condition of the birds; that is, whether they were laying or not. The greatest *changes, while laying, were in beef scrap* and shell consumption. The laying ration was narrower.

Graham[39] states that chicks do not grow faster or have less mortality on a free-choice diet, but the free-choice chickens, on the whole, were much more contented than the check lots and were much less inclined to feather pulling.

Funk[40] states that chicks were able to select a balanced ration and grow normally to 8 weeks if the necessary ingredients were accessible. *Results from the Minnesota*[41] *Station indicate that* chicks are able to select their correct protein level only when a high-protein mash is fed with the grain.

In a comparison of free choice of grain and mash mixtures, Amon[42] reported *no appreciable difference in weight* at 24 weeks, in mortality, or in rate of maturity.

The results with hens have been variable. Some reports[43, 45] indicate satisfactory production with free-choice feeding as compared with controlled feeding. *Other experiments*[42, 46] *favor the* controlled feeding.

Graham[47] reports considerable variation in the intake of whole corn, whole oats, and mash when hens are allowed free choice. The intake by an individual also varies from day to day and week to week.

A report from South Africa[48] shows that, with three groups of laying pullets fed mashes low, medium, and high in protein, *there was a tendency for the three groups to adjust the protein* to a common level by varying the relative amounts of mash and grain consumed.

Since birds fed free-choice usually consume a larger proportion of grain, mash concentrates, or mixtures containing higher amounts of protein, have been suggested for use with hopper feeding of grain. However, Kennard and Chamberlin[49] show that, whereas flocks varied greatly in the proportion of whole corn, wheat, or oats they consumed, *the proportion of total grain to* mash was comparatively constant and in proportion to the protein content of the mash. With free choice of grain, many feeders prefer the *higher protein* mash because of the natural tendency

for the birds to consume grain and hence less risk of a protein deficiency. Tomhave and Skoglund[50] report excellent production with New Hampshire pullets when given free choice of a 32 per cent protein concentrate and a mixture of corn, wheat, and oats. With Barred Rock pullets fed free-choice grain and 21 per cent protein mash, egg production was low and mortality high. In this case, the birds consumed too much grain.

Davidson and associates[51] report approximately 6 per cent of the deaths in White Leghorn pullets due to cannibalism under the all-mash system and approximately 36 per cent where mash and grain were fed by the "cafeteria" system. Von Ebbell,[52] reporting on cannibalism in laying hens, states that all remedies recommended failed to subdue the vice once started, with the exception of a cnange in feeding practice from free-choice feeding of grain and mash (which results in higher grain consumption) to rationed grain feeding. Kennard and Chamberlin[53] reported that feather picking and cannibalism became so firmly established in 6 groups of 70 Rhode Island Red pullets each, fed on low-protein (15 to 17 per cent) rations and whole grains, that it was necessary in controlling them to remove the upper beak by a special tearing process.

In all trials, it is noted that certain feeds are not consumed in quantities. Palatability is an important factor in the free-choice system. The feeds must be readily eaten by the birds. Probably, too, as in the case of continuous hopper feeding, regulation of some feeds at certain times may be necessary.

HOPPER FEEDING

Mash, grit, shell, and charcoal are usually hopper fed. Grain may be hand fed in the litter or hopper fed. The chief reason advanced for feeding grain in litter has been to induce the birds to exercise. The hopper feeding of grain is based on the assumption that laying hens do not need to scratch in litter, but get enough exercise in their regular activities. However, the feeding of at least part of the grain in litter helps to keep the litter in better condition than feeding all the grain in hoppers or troughs. With hopper feeding of grain, the hens can eat the feed quickly. This may be an advantage in winter. It might also assure hens going to roost with full crops. The free choice of grain usually results in a greater consumption of grain. Hopper feeding favors the saving of labor and ensures more correct

feeding where the poultryman is either inexperienced or cannot afford the time for regular hand feeding.

HOPPER FEEDING OF GRAIN TO HENS. Rice[3] reported no difference in egg production between two pens receiving grain plus beef scrap, one of which was hand fed the grain and the other hopper fed. Similarly, reports from other stations[4, 54, 55] show no difference in egg production where the grain is fed in litter or where it is hopper fed.

In Australia[56] an average production of 179 eggs, where grain was always before the birds, was obtained as compared with 164 eggs, where it was fed in the litter.

Other experiments[42, 55, 57] show better results where the grain is limited as in litter feeding. Free-choice feeding of grain and mash in these instances resulted in lower egg production, higher cannibalism mortality, and greater feed cost per dozen eggs. Greater variability in yolk color was produced by the free-choice feeding of grain. The difference was greater for Leghorns than for the heavier breeds.

In experiments conducted at Cornell there was no difference between feeding the grain in the litter or in hoppers in the case of hens. With pullets there was no difference in some trials, with a slight favor for the litter feeding in others (Table 17).

TABLE 17. EGG PRODUCTION OF HENS WITH HOPPER FEEDING GRAIN AT CORNELL

Year	Grain in Litter	Grain in Hopper
	Pullets	
1928	194 ± 4 5	193 ± 4 4
	200 ± 6 2	189 ± 4 4
1929	218 ± 5 5	217 ± 4 9
1930	226 ± 4.6	207 ± 5 5
1931	220 ± 5.7	214 ± 4 3
	211.3 ± 2 3	203 5 ± 2 2
	Hens	
1930	184 ± 3 4	184 ± 3 7
1931	159 ± 4.6	159 ± 3 9

In comparing hopper feeding of grain, with the hoppers open all the time, as contrasted to that with the hoppers open only at night, the New Hampshire Station[58] concludes that either system is satisfactory and that the birds adjust their feed intake to their requirements. In this trial the birds ate almost as much mash as grain.

In experiments conducted at Cornell comparing hopper feeding of grain at night only with grain available in hoppers all the time, the egg production was:

Year	Night Grain Only	Grain Available All the Time	Regulated Grain Available
1929	217 ± 4.9	215 ± 5.0	
	210 ± 3.5 216 ± 4.8	213 ± 4.8	
1930	207 ± 5.5	190 ± 6.5	
1931	214 ± 4.3		209 ± 4.7

The first year there was no difference in results. The next year the production was lower for those birds that had the grain available all the time. A study of the records, however, indicated that there were only a few times during the year when the production was not equal to that of the other pen and during those periods the birds consumed much more grain than mash. Consequently, the next year the birds were allowed constant access to grain, except when they ate too large a proportion of grain (more than 2 parts of grain to 1 of mash), in which case the hoppers were closed during the forenoon. This practice avoided the slumps with the result that there was little difference in the average yearly production.

Higher grain and lower mash consumption by the birds on free-choice grain emphasized the need of a mash with a higher content of vitamins and protein than is necessary for best results with the standard program.[58] Continuous hopper feeding of grain has been reported more successful when fed with a high-protein concentrate mash.[59] The Ohio Station[60] suggests the free choice of whole-grain and mash concentrate for layers primarily for farm poultry keepers, who produce their grains and who desire a minimum additional expense in balancing their poultry rations. Skoglund[61] suggests that the concentrate system is not as well suited to Leghorns as to the heavier breeds. Hays[62] concluded that with free-choice feeding of grain a high-protein mash was desirable for high-producing layers.

AUTOMATIC GRAIN FEEDERS

The feeding of grain by means of automatic feeders is similar in effect to the hopper feeding of grain constantly. The early automatic grain feeders were planned to give the birds more exercise by dropping grain in small amounts into the litter. Auto-

matic feeders were serviceable for people with irregular hours, since most people appreciated the advisability of regular routine in caring for flocks. The limitations of the automatic feeders are that they cannot exercise judgment in the balance of grain and mash, and do not enable or encourage close observation of the condition of the flock.

MECHANICAL FEEDERS. Mechanical feeders have been developed recently to automatically feed mash and pellets or grain to large flocks. These consist of a central hopper or feed supply from which run troughs to carry the feed through the house. The feed is moved through the troughs by means of a chain or similar contrivance. The movement of feed can be controlled so as to be continuous or intermittent. These automatic feeders are adapted to large flock operations of young or mature birds. They save time and labor in feeding and in many instances feed wastage. The mechanically fed groups eat more than corresponding hand-fed groups.

Reported trials[15] have shown no significant difference in egg production, body weight, or mortality for the mechanically fed lots as compared with hand-fed groups.

Both all-mash and grain-mash rations have been used with automatic feeders. All-mash high-energy rations have been preferred. It has been suggested that for maximum production it is necessary to supplement the all-mash mixture with pellets.[63]

WET VS. DRY MASH

The feeding of wet mash was one of the first supplements used in connection with grain feeding of poultry. It was usually fed one or more times a day, and the birds were given all they would eat. The dry-mash system, in which the dry mash is kept before the birds for a certain part or all of the day, came into use about 1900.

EXPERIMENTS WITH HENS. In 1907 Rice[3] reported an egg production of 129 eggs for hens having dry mash available all day and being hand fed grain twice a day, as compared with 121 eggs for hens being fed wet mash at noon and hand fed grain twice a day. Buss[4] also reported approximately the same production over a period of 2 years for hens fed the mash dry in hoppers or fed moist mash once daily in a trough.

Reports from Australia[56, 64] show an advantage in egg production in feeding supplemental wet mash. Results from England[65] show the lowest production when feeding wet mash only and im-

provement when the dry mash is supplemented with wet mash. The combination of the two proved particularly advantageous during the winter months. Body weights were also maintained more satisfactorily.

A report from South Africa[66] indicated more eggs from birds receiving dry mash than from birds getting a wet mash. In one experiment at Cornell, feeding wet mash only at noon gave a lower yearly egg production (141 eggs) than where dry mash only was available all the time (161 eggs). We find, however, in this case that most of the difference is traceable to one period, when feeders were changed and the birds consumed less food. When a wet mash was fed as a supplement to the dry mash, the results were not always consistent. Usually there is a small increase, especially during the fall and winter months (Table 18).

TABLE 18. WET-MASH FEEDING AT CORNELL

Method of Feeding	No Wet Mash	Plus Supplemental Wet Mash
All mash	179 ± 5.3	189 ± 4.7
Trough-fed grain + dry mash	193 ± 4.4	189 ± 4.7
	212	232 216
Litter-fed grain + dry mash	194 ± 4.5	200 ± 6.2
	136 ± 3.1	127 ± 3.3

The supplemental wet mash should be fed toward the middle of the day and preferably before the night feeding of grain, unless it is desired to increase the proportion of grain consumed. Where the supplemental wet mash was fed after the night grain, the birds consumed 49 per cent of the total feed in the form of grain, as compared with 44 per cent of the total feed in the form of grain where the supplemental wet mash was fed before the night grain or at noon.

Results from North Dakota[67] indicated that the feeding of a moist fleshing mash made little difference in the rate of egg production, percentage gain in weight, or mortality of either Rhode Island Red or White Leghorn pullets. The use of the moist fleshing mash materially decreased the consumption of whole grains and decreased somewhat the consumption of dry mash. Heavy feeding of grains was equally as effective as a moist fleshing mash in increasing the body weight of laying pullets, and, since egg production and mortality were not affected,

it was concluded that the producer receives no extra return for the time spent in making and feeding a moist fleshing mash.

The North Carolina Station[44] reported benefits from feeding yeast-fermented mash as compared with wet mash. The yeast-fermented mash, when fed both to White Leghorns and to Rhode Island Reds, stimulated the appetite and led to higher feed consumption and higher egg production. The birds also came into production more rapidly. In one test the mortality rate was also lower.

A survey of poultry farms in 1926, by E. G. Misner of the Department of Agricultural Economics at Cornell, indicated a greater production on those farms that fed wet mash the year round. These results were not confirmed, however, in a subsequent survey of 123 poultry farms for the year ended September 30, 1930. His conclusions from the latter survey are:

> *Rations now contain more dried milk products than a few years ago* They are more palatable. Illumination and the use of cod liver oil are more general. The advantage of using wet mash does not appear as great as when a study was made in 1926 Still, poultrymen using wet mash obtain three-fourths of a dozen eggs more than those feeding no wet mash.

	Number of Farms	Eggs per Hen	Per Cent Lay, October-December
No wet mash	28	140	20
Wet mash irregularly	51	149	21
Wet mash year round	44	147	26

In summarizing reports from pullet management campaigns in New York State, no difference in annual production was reported from farms feeding wet mash as compared with those using dry mash only. This might lead one to conclude that the use of wet mash does not help in sustaining high egg production. However, a flock that is vigorous and healthy and well housed can maintain good production without resort to wet mash or other encouragements to greater mash consumption. Very often it is only after a flock has failed to produce satisfactorily that the owner resorts to wet-mash feeding, hoping for improvement. Hence it may be to the credit of wet-mash feeding that results in such flocks are as good as they are.

EXPERIMENTS WITH YOUNG STOCK. In the production of table poultry conducted in England,[69] dry mash as a rearing ration gave better results than wet mash, but there was no differ-

ence between a dry mash and a combination of wet and dry mash. Other experiments[70] show no significant difference between dry-mash and wet-mash feeding for growing chicks.

ADVANTAGES OF DRY-MASH FEEDING. Some of the points in favor of the dry-mash system are:

1. Less labor.
2. Large flocks possible. All the birds have an equal chance for feeding.
3. No freezing in winter.
4. No must, mold, or sourness in summer.
5. Less apparatus required. Where large quantities of wet mash are used, mixers are necessary.

ADVANTAGES OF WET-MASH FEEDING.

1. More palatable if properly used. Stimulates food consumption, although this may be only temporary.
2. Less sorting and wasting.
3. Swollen feed.
4. Waste meat, table scraps, etc., readily included.

MASH FEEDING PRACTICE. The generally accepted practice is to keep the dry mash in front of the birds all the time as the main source of mash. The dry mash is then supplemented with a wet mash or pellets when it is necessary to maintain or increase food intake. (The regular laying mash can be used as satisfactorily as a special fattening mash.) Feeding a wet mash is not necessary all the time or when the birds are consuming enough food in the dry form. Feeding extra milk or increasing food consumption in other ways will have the same effect as feeding a wet mash.

High-protein mashes are often used. Davidson[71] reports slightly less total feed with such a supplement. Home-grown grains can be used to better advantage by using a high-protein mash. However, this increases the problem of supplying the vitamins.

FORM IN WHICH TO FEED GRAIN

Grain is frequently fed in the bundle, and corn is fed on the cob. They are fed so with the idea of saving threshing or shelling, or to give the hens more exercise. It is possible to accomplish these things, but we need to keep in mind that by so doing we may not know exactly how much grain we are feeding. The tendency is to underfeed on grain rather than to overfeed. Besides, there is a rapid accumulation of straw or cobs which needs to be taken care of. Straw probably will need to be re-

moved more frequently than is necessary for sanitary purposes.

Shall the corn be fed whole or cracked? Feeding whole corn has certain advantages, such as decreasing the danger of spoiling, avoiding the loss of part of the grain in cracking, and more readily determining the quality. As long as the kernels are not too large, it can be fed. If whole corn is to be fed to the hens, it is advisable to begin feeding the same to the pullets on range. The basis for feeding cracked corn is to produce a larger number of particles and induce the hen to greater activity, that is, to give her more exercise. *Activity is necessary to make the hens healthier, to strengthen the muscles, to make them eat* more, and to produce heat and body activity, which is essential for production. The feeding of finer particles probably depends upon whether or not the bird gets enough exercise in its ordinary activities. Some think that a hen will eat more whole corn because it can be picked up quickly. This, however, does not necessarily hold true. Often the hens will eat more of the cracked corn, in which case it might be an advantage to feed it.

Soaking grain in milk or water has also been practiced.[72] Hadlington reports that a flock of 150 pullets fed for 3 months on soaked wheat showed higher return over cost of feeding than the flock fed on the ordinary ration. Newman states that the *soaking of grain for 24 hours is an economic proposition*, resulting in improved health, better production, and a slight reduction in the amount of food consumed.

In a study of palatability of grains, Newbigin and Linton[73] state that "one fact stands out clearly in this experiment, and that is that the first four foods selected by the chicks, namely, millet, canary seed, dari, and hemp, are the only grains (with the exception of linseed) offered to the chicks in their natural state, i.e., neither decorticated nor kibbled. It may, therefore, be that the deciding factor in the natural selection of food by *young chicks is the condition in which they are offered*, 'natural' foods being selected in preference to 'treated' foods."

PRACTICES IN CONNECTION WITH FEEDING LIQUIDS

Is it necessary to feed both water and milk when we are using liquid milk as our source of animal protein feed? That will depend to quite an extent upon the season of the year and the extent to which it is necessary to have the birds consume the liquid product. It will depend upon whether milk is being supplied as a food or drink or both. *If the birds are not getting any meat scraps*

in their mash, it will be necessary to restrict and sometimes entirely eliminate the water in order to get them to consume sufficient quantities of milk. On the other hand, if we restrict the water or eliminate it, we need to use the milk as their drink also. Under those conditions, they are likely to consume larger amounts of the liquid milk than are necessary. This would not be economical. Where the birds get meat scrap in their mash, usually a combination of water and milk is used. Both are kept available or the milk is fed alone until consumed, at which time water is supplied.

The question is often asked whether it is necessary to warm the water in the winter.[74] If the water is too cold, it will not stimulate consumption, and we need to get a considerable water consumption in order to have the birds function properly. Records from Oregon indicate that pullets drank 25.4 per cent more warmed water than cold water during freezing weather and that water consumption was increased 5 per cent per pullet and 4.2 per cent per 100 eggs laid by warming it during average western Oregon winter weather, in which the temperatures were above freezing 90 per cent of the time. Beresford, reporting results obtained in Idaho, states that the pens receiving 40 to 50 F. degree water gave an egg production record decidedly in favor of the pens receiving the warm water. In these pens also 20 per cent more water was consumed.

Frequently hot water is used to mix a wet mash during cold weather because some think that a warm mash is more appetizing.

Therefore, it is advisable at least to take off the chill from the water in cold weather. Where heating appliances are used to keep the water from freezing, this is automatically taken care of. Otherwise, warm water can be furnished two or three times a day.

On the other hand, a cool drink in the summer is also relished by the hen. Anything that will increase the contentment of the birds will probably have its effect on production.

COOKING FEEDS

A number of years ago it was quite common to cook feeds for poultry. With the increase in the size of flocks, this practice has very largely disappeared. Certain feeds, such as beans and potatoes, seem to be improved for poultry by cooking. Cooking involves extra equipment, expense, and labor, which it is doubtful are repaid in results.

RANGE VS. CONFINEMENT

The question of range as compared with confinement resolves itself into whether or not the birds are getting what is necessary for them. The favorable results previously obtained by free range, as compared with confinement, are due probably not so much to the fact that the birds had free range as to the fact that they were getting nutrients under free-range conditions, which they were not getting when they were kept confined. It is possible to restrict birds to comparatively small areas and get just as good results if they are getting the same nutrients as birds on free range. Access to outdoors, for exercise and sunshine, and provision for green feed will give just as good results as running on the range. Poor results from confinement are due to a deficiency in the ration rather than to the fact that the birds did not have a chance to range. With the development of commercial poultry keeping the practice is for greater confinement of both growing chicks and laying stock. In addition, many poultrymen are now keeping their chicks for the first few weeks of life in battery brooders, where the amount of space provided is much more limited than in ordinary confinement.

These changed practices in management, as well as new developments in methods of feeding, have brought the manner of feeding strongly to the attention of poultrymen and have led to the belief on the part of some that the newer systems of feeding might be responsible, in some unknown manner, for certain of the difficulties occurring frequently in poultry. The belief, however, is not well founded. It should be remembered that the confinement of poultry has brought about restriction of exercise and a change in the nature of the ration. As long as unlimited range was provided, hens were to some extent independent of the ration supplied, for they were able to supplement this ration with succulent green food, bugs and worms, and other poultry titbits, the food value of which, except for the green feed, is little known. Furthermore, restriction of exercise and confinement to the neighborhood of the feed hoppers has caused greater feed consumption, which in turn has stimulated growth and egg production.

Confinement has given better control of sanitation and other conditions. However, a complete ration and more exact feeding and management are required to prevent vices and troubles.

FEED RESTRICTION

Heywang[75] showed that restricting the amount of diet intake to 75 per cent and 87½ per cent of the amount consumed by the group fed on an ad libitum basis caused a decrease in the total average number of eggs produced but did not affect the average size of the egg laid by the fowls in the different groups or the average body weight of the fowls.

Burmester and Card[76] report the effect of restricted feeding time when feeding an all-mash ration and pellets to Leghorn-Rhode Island crossbreds kept in individual laying cages. With the all-mash ration, body weight and egg production declined rapidly when hens were restricted to less than 6 hours of feeding time each day. The mash-fed hens, when restricted to short *feeding periods, would eat continuously for more than an hour,* when feed was offered, in an effort to get sufficient total food. Hens fed pellets could eat a given quantity of feed in a much shorter time and hence were able to maintain their weight and to continue to lay while on feeding schedules as short as 2 hours daily in one continuous period, or 20 minutes every 12 hours.

Temperton and Dudley[77] found that restriction of food of laying pullets, under a system of dry-mash feeding, resulted in lower egg production and lower final body weight, as compared with birds fed ad libitum. Where pullets had access to mash on only 6 days of each week, there was little difference in egg production; final body weights were slightly in favor of the unrestricted birds; there was a 6 per cent saving of feed in favor of the restricted feeding. Taylor[78] found production not as good where hoppers were closed 2 hours a day as where they were open all the time and a decided decrease in production where the hoppers were closed one day a week.

Fangauf and Haensel[79] report that, when hens have free access to mash, the restriction of the amount of grain fed will cause an increase in mash consumption so that there is not much difference in total food intake.

Kennard and Chamberlin,[80] in comparing various rations and methods of feeding layers, conclude that any of the methods may be safely recommended with the possible exception of the one which provided a 32 per cent protein mash and restricted the free choice of corn and oats to 2 hours daily.

Restricted feeding of pullets[82] has been reported as retarding growth and delaying sexual maturity but having no material effect on subsequent performance.

Temperton[81] restricted the mash consumption of pullets on

range by limiting the time during which the birds could obtain mash. There was a much greater consumption of grain in those groups to which the mash was restricted so that the net saving in feed was 5.6 per cent, with only a small difference in body weight at the end of the rearing period. Temperton and Dudley[83] reported that the general result of restricting feeding during the rearing period to 80 and 90 per cent of the amount consumed under unrestricted feeding has been a lower final weight at the end of rearing for the restricted groups. There appear to be no important after effects of the rearing restrictions in the subsequent laying period of pullets reared on restricted rations but with unrestricted rations during the laying period. With pullets reared on restricted rations and with the restriction of mash during laying, there is a tendency for egg production, or body weight, or both, to be below the corresponding characteristics for birds fed "ad lib." Quicke and Kellerman[84] report that after 10 weeks of age weekly 48-hour fasts had no apparent detrimental effect on the growth and mortality of cockerels during a test period of 24 weeks with a saving of 17 per cent in food consumption. The pullets, however, were affected detrimentally especially during the laying period. Feeding small amounts of green feed during the fasting periods proved advantageous.

Edgar and Herrick[85] tested the susceptibility of chickens to coccidiosis when they had access to feed at all times or were not fed until after 7:00 A.M. In every instance the chickens that had access to feed at all times were more resistant to coccidiosis. The difference in susceptibility was believed to be sufficiently great to justify recommending that poultrymen keep feed before chickens at all times.

In observations on ad libitum and restricted feeding, in chickens a day to 12 months old, Novikoff and Biely[86] found that the restricted feeding involved a greater amount of labor and resulted in somewhat lower rate of growth and egg production, with no significant differences in the pathology of the two groups of birds.

SUDDEN FEED CHANGES

Sipe and Polk[87] report that suddenly changing the feed of laying birds did not reduce egg production during the first month after the change or cause the birds to molt. Berg and Bearse[88] reported that suddenly changing the texture of the mash or changing from mash to pellets and vice versa did not affect the

rate of lay. O'Neil[89] concluded that sudden feed changes had a deleterious effect on production and that changes in the color of the mash may be an influencing factor.

Platt[90] reports on emergency changing of the ration during the winter. Removing the mash but feeding grain ad libitum did not affect egg production adversely unless continued for more than 6 days. Removing the grain resulted in a marked drop in production.

Whether or not sudden feed changes will affect production appears to depend on the way in which the change influences total feed intake and restriction of the necessary nutrients.

GENERAL SUMMARY

A review of the different systems and practices would seem to indicate that the method or system does not appear to be the important thing. The important factor seems to be whether the birds consume as much feed under one condition as another and whether, under that method of feeding, they are getting a proper balance of nutrients in their feeds. Hence, it probably comes down to a matter of balance of the ration combined with palatability so as to get sufficient feed consumption. Method in itself is not the important factor.[91]

If frequent minor variations are disregarded, there is one method much more commonly used than any other. It may be called the scratch-mash system of feeding. In this system, poultry is given two feed mixtures, one consisting of whole and cracked grains and the other of ground ingredients. Several years ago a decided variation from the scratch-mash system of feeding, called the all-mash method, was developed. A combination of these two systems of feeding has come into extensive use for rearing chicks. In this system, an all-mash ration is fed during the first month or two after hatching, and a ration consisting of a scratch mixture and a growing mash thereafter to maturity.

Acceleration in growth and increase in egg production have put greater strain on the body of the bird and therefore greater demands on the ration fed. Therefore, if the system of feeding practiced makes it possible to get sufficient daily feed consumption, emphasis should be laid not on manner of feeding but on the nature of the ration used. Any difficulties not caused by disease or inherited weaknesses are in all probability due to the use of rations partially deficient in one or more of the essential nutrients.

Rations for feeding poultry should be complete in all nutritive factors. When birds are confined, it becomes more difficult, but not impossible, to meet this requirement because succulent green feed of the proper type and bugs and worms have been automatically removed from their ration. Many nutritive factors needed by hens, but still undiscovered, may be contained in these natural food materials picked from the range. The way out of such a situation is to make use of the so-called protective feedstuffs, such as milk, green feeds, and vitamin-rich feeds, in building poultry rations.

Wide variations in feeding methods are possible as long as they do not make it impossible to get sufficient daily food consumption, or interfere with the building of a ration complete in all essential nutritive factors With these limitations in mind, there is no one best way of feeding poultry.

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CHAPTER 11

HEALTH FEEDING

In order to keep in a healthy and productive condition, an animal must be furnished a ration complete in all respects. If there is something lacking in the feed, production or health, or both, will suffer. The so-called nutritional diseases are the best examples of a deficiency condition. They are due chiefly to a lack of vitamins or minerals in the ration. For example, if vitamin D is not supplied, the bird will suffer from rickets. Perosis may result if the chick does not get enough manganese. These specific nutritional diseases or deficiencies are discussed in detail in Chap. 3 dealing with vitamins and minerals.

RELATION OF THE DIET TO HEALTH

We must always keep in mind the fact that the ration may have an effect upon the health of the animal and the incidence of disease, particularly in middle and old age. In comparing a rat colony on a good diet with one on an ill-balanced diet, it was found that the well-nourished animals showed no illness, no death from natural causes, and no infant mortality, whereas the poorly nourished animals showed indications of a number of diseases and disorders.[1] Apparently, diet is important in the preservation of healthy cells and tissues with consequent normal function.

The Iowa Experiment Station[2] reported that the ration might have an effect upon the incidence of so-called range paralysis A report from Northern Ireland[3] has shown that the addition of supplements of limestone flour to a complete rearing ration impaired the health of the birds and increased the mortality due to coccidiosis. Other experience also indicates that an excess of calcium in the chick ration will depress growth (See Chap. 3 on minerals.)

One report indicates gout as being caused in chickens that were fed too richly with lime.[4] Besides too large a quantity of lime, other causes have been given for the development of gout[5] It is usually influenced by many months of one-sided feeding and

confinement. It is also looked upon as a disease connected with metabolism.

One of the benefits of milk feeding is attributed to its development of the aciduric or lactic acid bacillus group of bacteria in the intestines. They are favorable bacteria. On the other hand, meat and other high-protein diets increase the indo-producing bacteria and other organisms of the so-called putrefactive type.[6]

The severity of coccidiosis has been influenced by the type of ration fed.[7-12]

An adequate supply of the various nutrients is essential for resistance to disease. Boari[13] reported that chicks on a vitamin-deficient diet infected with *B. avisepticus* acquired immunity with much more difficulty. Seeler and Ott[14] reported more severe avian malaria infections in chicks when the diet was deficient in folic acid, protein, and unidentified factors.

Diet has a relation to the development of internal parasites. Results from the Kansas Station[15] showed that the resistance of chickens to parasitism was affected by vitamin A and vitamin B. The inclusion of liquid skimmilk and meat meal as supplements in the diet increased the growth rate and the resistance in the chicken to the nematode *Ascaridia lineata* but that the plant diet produced the slowest growth rate and the least potent resistance in the chicken to the growth of the nematode. In the case of chicks infected with *Eimeria tenella*, it has been reported that vitamin K in their food showed a mortality of only 10 per cent in comparison to 70 per cent mortality in the unprotected group.[16] Chickens receiving a diet deficient in calcium and phosphorus were less resistant to infestation with the nematode *Heterakis gallinae* than were those receiving the same diet to which adequate amounts of calcium and phosphorus compounds were added.[17]

POISONS IN FEED

The health of the animal may also be affected if the feed contains some harmful substance or if the animal consumes some material which is detrimental. When the poultryman suffers losses, one of his first reactions is to blame the feed and to suspect that it contained something poisonous.

A number of years ago the American Feed Manufacturers Association issued a publication entitled Was It the Feed? In this publication are presented the replies of state representatives of the Association of American Feed Control Officials who

were asked for résumés of actual cases of suspected feed toxicity which were referred to them for investigation. The following observations are representative of the replies.

Dr. H. R. Kraybill of the Indiana State Agricultural Experiment Station reported as follows:

> Recently I have summarized the results of the examination of 689 samples that have been submitted during the last 10 years. Only 4 of these samples showed the presence of harmful ingredients. In one of these cases, powdered arsenate of lead was accidentally spilled into the feed. In another case, through accident in mixing, 37 per cent of salt was present. In some instances, animals that have died were submitted with the samples of feed. These animals were autopsied by the Department of Veterinary Science, and, in practically every case, disease was found to be present which would account for the death of the animal.

Mr. Leas, in charge of the feed inspection work in Ohio, wrote as follows:

> Every year we have around 150 such cases. They write that they are sending the feed that [they think] has killed their chickens and want to know whether or not the feed has been responsible. Our chemist gives them a microscopical examination, analyses of protein, fat, fiber, etc., and then we feed them to guinea pigs and obtain the starting weight and final weight of the guinea pig In only 1 case out of over 1000 samples received have we found any poisonous effects of the feed.

In Maryland, of 61 samples of feed suspected of having killed chickens, some of which were accused of killing birds by the score, not a single one was found to kill healthy birds even though the possible deleterious effects were greatly magnified by giving the feed as the entire ration after a starvation period. The Nebraska Station pointed out the typical complaint as this: "We used this feed and lost a lot of chicks. Please analyze and tell us what is in it that is killing them." In their experience, in testing feeds over a period of years, they state that in one case the ration submitted was unusually laxative because of too much molasses, but losses were not excessive. In all other cases, no abnormal losses were observed.

In most cases, it has been shown that the feed did not contain any poison or harmful material. In a small number of cases, losses have been attributed to the presence of poison, usually lead arsenate or Paris green. This might have become available to the stock either through malicious intent or through carelessness. In one case, it was found that the feed was contaminated with arsenic dusting powder in the warehouse. In another case, an old paint barrel was used for molasses. Some-

times it might be traced to letting the stock have access to certain materials about the premises, such as empty paint cans. Or they might have eaten decayed animal matter, secured from dead animals.

Losses may also be attributed to faulty management, such as maintaining insanitary conditions and improper changes in feed, but more frequently the cause of losses is traced to the presence of disease. One feed control official pointed out that during the baby chick season a sudden wet, cold spell of weather is very likely to be followed by an influx of complaints of feed that is suspected of being poisonous.

LOSSES DUE TO INSECTS

Chickens on range may consume considerable amounts of animal life, such as insects and worms. In general, they can do this without harm. However, it has been reported that chickens, ducklings, goslings, and young turkeys may be killed by eating rose chafers.[18] Healthy chicks, usually between the ages of 2 and 14 weeks, may suddenly act sleepy and listless and die on range with full crops. On examination, the crop may be found to contain rose bugs or chafers in large numbers. The rose chafer has in it a poison that affects the nervous system. Hens usually are not killed by eating these insects.

Mortality in turkeys has been reported due to the feeding of grasshoppers.[19] Enteritis due to injury from the legs of the insects which even punctured the intestines, was observed. One precaution suggested was the feeding of a liberal quantity of mash in the morning.

Mortality in pigeons due to the pea beetle (*Bruchus pisorum L.*)[20] has also been accompanied by inflamed and swollen intestinal lining.

POSSIBLE LOSSES TRACEABLE TO GRAINS

In the feeding of moldy corn, Gibbs[21] reported that severe intestinal reactions occurred in all the chickens when first placed on the moldy corn ration and one died of enteritis. After feeding on moldy corn continuously for 4 weeks, the chickens apparently developed a tolerance and did not show any further ill effects. Ronk and Carrick[22] fed moldy corn to laying hens for 30 days with no ill effects. Chicks receiving 20 per cent of moldy corn and 30 per cent of good corn grew as rapidly as those receiving

50 per cent of good corn. The chicks receiving 30 per cent and 40 per cent of moldy corn, however, grew less rapidly. No apparent deleterious effects resulted when chicks received moldy corn that was infected with species of penicillium, diplodia, fusarium, mucor or rhizopus, aspergillus, and undetermined organisms, including yellow bacteria. There were no apparent mortalities due to the feeding of moldy corn, except possibly one due to aspergillosis. Borchers and Peltier[23] added 10 per cent of a moldy foodstuff, consisting of a mixture of wheat bran, corn, and soybean meal prepared under controlled conditions with selected mold isolates, to a chick starting ration without any apparent deleterious effect.

The feeding of scabby barley or wheat to chicks, growing chickens, or laying birds has had no apparent effect upon rate of growth, mortality, or production.[24, 25] The Maryland Station[26] has reported on the use of field-damaged wheat for poultry. No detrimental results were noted in the feeding of it to hens for a period of 6 weeks. The wheat was highly discolored, with a large percentage of the grain sprouted and slightly moldy. However, in using such wheat, they recommend the following: "Use only as a part of the ration and if fed heavily use each alternate month. If possible run the wheat through a fanning mill to blow out dirt and mold. If the wheat is molded badly, heat in an oven to kill the mold spores. Feed only during good weather and when diseases are not prevalent."

The feeding of new wheat to chickens has been reported as favoring the development of blue comb disease.[27] Feeds associated with this condition have been reported to be high in bacterial floras. On the other hand, heavy feeding of new wheat is reported by the Ohio Station[25] as being not detrimental when fed to growing birds or laying pullets.

The question frequently arises as to the use of wheat or other grains which have been treated for the control of plant diseases. The reports seem to indicate that grain treated with eosin[28] or mercury compounds are quite harmless when treated in the ordinary way and fed in regular quantities. On the other hand, unfavorable results have been obtained with grains treated with certain compounds. It would appear desirable to feed any treated grain to a small number of birds before using it generally or in large amounts.

The question also frequently arises as to the possibility of using for the feeding of poultry grain which is affected by smut. Horvath[29] reported that 4 per cent of corn smut added to the

diet for 3 months was not injurious to hens and did not affect their chemical blood composition or egg-laying capacity. The Oklahoma Station[30] gathered the sorghum heads from a field in which 70 per cent of the heads were infested with a kernel smut, determined the number of damaged kernels, and estimated the amount of smut. The spores of the smut were fed to young and grown chicks without any apparent effects on growth, egg production, or hatchability. The Oklahoma Station[31] also indicated that the feeding of 12 per cent of kafir smut mixed in the mash, or smutty wheat used in the mash, did not decrease egg production, fertility, and hatchability, where the ration was otherwise adequate. The Maryland Station[32] used wheat damaged with stinking smut as a poultry food with reasonably satisfactory results from the standpoint of palatability and the absence of deleterious effects, although its feeding value appeared somewhat reduced owing to the destructive action of the smut.

Caution is usually advised in connection with the feeding of grain affected with ergot, since it has been reported that the presence of this fungus would cause diarrhea. Lobl[33] reported poisoning by ergot. He stated that the chickens hopped about like sparrows. The toes of some of them were mummified, and of others swollen and soft. In some cases, the skin broke loose from the sole.

Aspergillosis[34] is a disease caused by the aspergillus mold, the mold which grows on damp feed. It produces spores that blow about when the feed becomes dry. If these spores are inhaled, the disease results.

It has been reported that young chicks fed on barley died in a few days. Examination showed that coarse barley hulls cut the intestines to ribbons. Irritation of the eyes caused by barley barbs from the litter has also been observed in chicks.

LOSSES DUE TO TOXIC PLANTS

Hart[35] reported that seeds of *Araujia sericifera* proved to be toxic to fowls in three feeding experiments with White Leghorn roosters. The toxic principle caused enteritis, incoordination of movement, and loss of balance and of muscular control. Toxicity increased with maturation of the seeds. Five grams of ripe seeds proved lethal.

In the feeding of cocoa wastes to poultry, Temperton and Dudley[36] reported that death occurred even when only 10 per cent of this food was included in the daily ration. The theobromine

content of this ration was 1.9 per cent. They suggested that the only satisfactory method of avoiding risk is to use only cocoa bean products from which the theobromine has been removed, but the cost of this would make the price too high. The bird appears perfectly healthy and may even be in the act of consuming food when it suddenly becomes rigid for a few seconds, falls back contorted with muscular spasms, and dies. After death, the limbs are fixed and the joints immovable for a few minutes, but later the whole body becomes limp and rigor mortis follows after the normal interval. Upon post-mortem, no obvious cause of death can be found.

The seeds of corn cockle (*Agrostemma githago L.*) have been shown to be toxic to chickens,[37] as well as to other animals. The poisonous principle is a glucoside found in all parts of the plant, but mainly in the seed. Birds affected with cockle poisoning present a generally listless or sleepy and unkempt appearance, with rough feathering and diarrhea. Characteristic lesions of cheesy material in the mouth and under the tongue have been reported. Cockle poisoning decreases the respiratory rate and heart rate of the bird. The resistance of the bird to coccidiosis, paralysis, fowl pox, and diphtheria has been reported decreased, even when sublethal doses have been fed. In the case of chicks, lesions were observed even when very small amounts of ground cockle were added to the feed, but weight was not affected until more than 2 per cent of ground cockle was added. Larger amounts finally resulted also in mortality. Larger amounts of the ground cockle are necessary to secure like results in older birds. Older birds seem to have developed a tolerance to the poison. Whole cockle is unpalatable and, when fed in that form, usually will not be consumed in large amounts. But whole cockle can be consumed in large quantities without any very serious detrimental effects.

Certain species of crotalaria seed[38] have been shown to be toxic for chickens, quail, and doves. The seeds are not relished and will not be eaten in large quantities, except under unnatural conditions, such as close confinement with constant access to the seed.

Daubentonia seed poisoning in poultry has been reported by the Florida Station.[39] The seed is highly toxic to poultry, and death occurred soon after the seeds were consumed.

The toxicity of *Glottidium vesicarium* Harper seeds for fowls has been reported by the Florida Station.[40] Well-fed birds usually refuse to eat the seeds voluntarily Semi-starved birds will

eat some of the seeds but usually not enough to prove fatal. However, a number of cases of natural poisoning by the seeds have been observed.

It has been reported that hedge mustard (*Erysimum crepidifolium*)[41] is readily eaten by geese and has often killed off a whole flock in a few hours. The whorled milkweed has been reported as a poisonous plant for poultry[42] and for turkeys.[43] The top parts of the plant are more toxic than the roots. The birds show inability to stand, together with spasmodic twitchings of the limbs and head. Immature tender plants appear more toxic than the more mature weed. The birds will not consume much of the weed if they are provided with sufficient wholesome green feed.

Losses have been reported from the consumption of mustard seed and also from plants which produce hydrocyanic acid in the intestinal tract.[44]

Parsley[45] is a very potent herb which should rightly be considered more as a medicinal plant than as a poultry green feed to be used freely. The whole parsley is a poisonous plant. Most varieties of cultivated or wild parsley are fairly toxic for fowls, and the roots are even more so than the leaves.

Potato or solanin poisoning[46] has been reported in ducks which have been fed on cooked sprouted potatoes. The green sprouts of potatoes contain a considerable amount of the solanin. It has been suggested that one should never use the water in which potatoes have been boiled for mixing a wet mash, particularly when the potatoes have commenced to sprout.

Tar weed seed,[47] which has been shown to be toxic for swine, horses, and calves, has been reported as not being toxic for poultry, when occurring in the usual amounts in unscreened western wheat.

A number of other plants have been reported as being poisonous to poultry. They include the leaves of white snake root, black night shade,[48] particularly the green berries, leaves of lily of the valley, sprouts of cocklebur, and pokeberry and Jimson weed seeds, seeds of the lead plant,[49] and some vetch seeds.[50]

Whole wheat frequently gives better results, especially in fattening, than wheat by-products. In some cases, this may be explained by the fact that the by-products contain some of the injurious seeds, such as cockle, ergot, and darnel.[51]

LOSSES DUE TO CHEMICALS

A case of poisoning by acetic acid has been reported for fifteen chicks in a house, the floor of which was covered with beechwood sawdust on which the sun was shining. This was thought to be a case of poisoning by inhalation.[52] Sodium bicarbonate and boric acid have been reported injurious to chicks.[53]

Arsenical poisoning has been reported in the fowl.[54] Arsenical preparations, among the most useful insecticides, are used in dips against ticks, internally against worms, as a spray, and as bait for locusts. It has been shown that when arsenic is administered in small quantities such as in poison bait for grasshoppers, or in spray for fruit trees, the domestic fowl can tolerate comparatively large doses over a long period without any visible ill effects.[55]

Copper compounds are toxic for domesticated birds.[56] Copper sulphate poisoning has been reported as due to the feeding of wheat treated with copper sulphate for mildew or to giving a copper sulphate solution as drinking water [57] Copper sulphate poisoning commences clinically with blue-green diarrhea, falling out of plumage, loss of appetite, and vomiting. Death is accompanied by cramp. Copper sulphate solutions are frequently used for the prevention and control of certain diseases. Water containing more than 0.25 per cent (1–400) copper sulphate was found to be deleterious to the health of turkeys when given as the only source of drinking water.[58]

Fluorine toxicosis has been reported to inhibit egg production. Since fluorine is a cumulative poison, caution must be exercised in the use of mineral supplements containing fluorine in poultry feeding.[59] Similarly, other common minerals present in feeds may be harmful when fed in excess (see Chap 3, p 25).

Nicotine is frequently used in the control of round worms in chickens. However, high levels of nicotine must be avoided since they will affect the growth of the chicks and increase mortality [60]

Poisons used in vermin extermination have been the source of poisoning.[61] The most characteristic symptoms of thallium poisoning in chickens are bluish discoloration of the comb and wattle, paralysis of the legs, diarrhea, and loss of feathers Young chickens appear to have a greater power of resistance against thallium poisoning than older birds. Zinc phosphide and sodium fluoroacetate have also been reported as being toxic Toxicity symptoms have also been shown after the administration of DDT.

Carbide poisoning in hens,[62] colchicin[63] poisoning in ducks, and naphthalene[64] poisoning in hens have also been reported.

The general symptoms of poisoning are depression, ruffled feathers, general debility and unthriftiness, purple comb, diarrhea, and inflammation of the intestinal tract.

In general, toxins act qualitatively in the same manner on birds as on mammals. Quantitatively, there are great differences between birds and other animals. Birds are very sensitive to a few poisons, such as cyanide and carbon monoxide, alcohol, and nicotine. On the other hand, they are less sensitive than mammals to other poisons, such as urea, arsenic, and nerve poisons.[65]

SALT POISONING

Too much salt is toxic.[66] The symptoms of salt intoxication are inability to stand, intense thirst, pronounced muscular weakness, and convulsive movements just before death. A viscous discharge from the beak has also been noted, as well as symptoms of paralysis and blue comb. Post-mortem examination reveals edema and lesions in many organs, but particularly hemorrhages and severe congestion in the gastro-intestinal tract, muscles, liver, kidneys, and lungs.

The toxicity of salt seems to depend to some extent upon the manner in which it is administered, the presence of water, the age of the birds, and the resistance which has been developed toward it. The minimum lethal dose seems to be about 4 grams per kilogram of body weight or 0.4 per cent of the body weight. Young stock can assimilate greater quantities of salt than adult birds. Concentrations between 0.5 per cent and 0.9 per cent salt in the drinking water produced extreme thirst, short rapid breathing, and edematous swelling within a few days. Ducks have been reported to be more susceptible to salt poisoning than chickens.[67]

POSSIBLE HARM FROM DRUGS AND HORMONES

Considerable attention has been devoted in the past few years to hormones and their effects on the animal. Caution must be used in the application of hormones to feeding, since they might have deterimental effects. For example, thyroid, when given in excess, will retard the rate of growth or even cause a loss of body weight.

A number of sulfa drugs have been used for the prevention and control of poultry diseases. It is necessary to exercise precaution in their use and feed according to directions, since large dosages may be harmful.[68]

LOSSES FROM CANNIBALISM

Management and environment are important factors in avoiding or controlling losses from cannibalism and feather picking. However, it is also recognized that the ration and feeding management might have an influence in this respect. Malnutrition[69] due to a deficiency of protein, minerals, or other factors might of itself result in an increase in cannibalism and feather picking.

POULTRY FEEDING FROM THE PATHOLOGICAL STANDPOINT

Much can be done to maintain the health of the flock by proper attention to feeding management. One program along this line is given by Axworthy,[70] in which he suggests that the following be avoided. (1) Excess fiber in the mash or poor quality meals of a fibrous nature. They might result in infection of the gizzard, inflammation of the intestinal tract (mechanical enteritis), and inflammation of the kidneys (secondary). (2) Lack of fiber. This might result in pasted beaks and impacted crops. It is likely to be accompanied by loose, bad-smelling diarrhea, intestines filled with a mucoid pasty mass, and an atonic condition of the intestinal tract. (3) Excess protein. This may be accompanied by enlarged and inflamed kidneys (nephritis) and ureters distended with urates (4) Unpalatable mash. This might result in depraved appetite, causing the eating of litter, and a mechanical enteritis (5) Stale or moldy food. This might result in the development of aspergillosis (6) Overfatness. The hens are likely to be more susceptible to disease such as egg peritonitis. (7) Sharp flinty substances. They may cause laceration and inflammation of the intestinal tract.

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CHAPTER 12

FEEDING AND MANAGEMENT OF YOUNG CHICKENS

The object to be accomplished in the feeding of young chickens is to grow strong, well-matured, normal individuals with little or no mortality, at a cost that is consistent with good results.

CHANGES IN WEIGHT DURING GROWTH

One of the purposes of a chick ration is to produce normal growth. Normal growth refers to the weights, limited by inheritance, which the chicks should attain when kept under favorable conditions. It is necessary to keep in mind, however, that the rate of growth is subject to variation, depending upon breeding, management, and environmental conditions. Hence there are definite standards for each variety or strain which has a different weight at maturity.

The actual weights of chicks, and especially the weights during the early growth period, have improved owing to advances in breeding, feeding, and management. Weights and feed consumption representative of earlier results[1] have been bettered by more recent figures shown in Tables 19 and 20.

There is very little difference in the growth of chickens that are reared indoors or on range when they are fed equivalent rations. However, Kentucky[2] reported that the pullets and cockerels reared indoors and without direct sunshine were not so vigorous and active or so healthy in appearance as those reared outdoors.

The time of hatching does have an influence upon growth. The general tendency is for early hatched chicks to grow faster than late-hatched chicks.[3] However, Kempster[4] also reports that these differences may be explained on the basis of high temperatures during the growing season. The type of growth curve, therefore, varies, depending on the date the chicks are hatched and the temperatures that prevail during the growing season.

The energy of the young stock is thrown into growth and motion. If either growth or activity is stopped for any period of

TABLE 19. GROWTH AND FEED CONSUMPTION OF CHICKS

Age in Weeks	Body Weight Per Bird, lb. Cockerels and Pullets 50-50 (except as noted)		lb. Feed per lb. Body Weight to Age Shown	
	Leghorns	Heavy Breeds	Leghorns	Heavies
1	.15	.19	.8	.8
2	.25	.33	1.4	1.3
3	.36	.51	1.6	1.5
4	.55	.77	1.9	1.8
5	.78	1.2	2.2	2.0
6	1.2	1.5	2.5	2.2
7	1.4	1.9	2.6	2 3
8	1.7	2.2	2.7	2 5
9	2.0	2.4	2.8	2.7
	Pullets Only		Pullets Only	
10	1.9	2.5	3.3	2 9
11	2.1	2.9	3 4	3.1
12	2.3	3.3	3.6	3 3
13	2.5	3.6	3.9	3.6
14	2.7	3.9	4 2	3.8
15	2.9	4 3	4 4	4 0
16	3.1	4 6	4 7	4.1
17	3.2	4.9	5.1	4.2
18	3.3	5.2	5.6	4 3
19	3.4	5.4	5.8	4 4
20	3 5	5.7	6.1	4 7

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TABLE 20. GROWTH AND FEED CONSUMPTION OF S.C W LEGHORN FEMALES AT CORNELL UNIVERSITY

Age in Weeks	Average Weight, lb	Total Feed Consumed, lb
2	0.28	0.49
4	0.64	1.55
6	1 10	2 91
8	1.30	4.06
12	2.14	9.36
16	2.77	13.84
20	3.36	18.86
23	3 73	23.16

time, the results will not be favorable. Both must continue steadily according to the laws of growth. Growth represents increases in tissues, such as bones, muscle, skin, feathers, and nerves. Besides water, these increases are chiefly in protein and minerals.

GROWTH RELATIONS

Before we can consider chick feeding intelligently, it is necessary to be familiar with the way the chick grows. With poultry in general, we have very rapid growth early in life. This growth is more rapid than in any other farm animal. Although the average chick will double its weight in about a week to 10 days, it is not unusual to find individual chicks doing this in a week. It is unlikely, however, that it will again double its weight within a like period of time.

RATE OF GROWTH. The mode of growth or percentage rate of increase[5] varies with age. Average weekly gains are greatest during the first month or 6 weeks. During the next month or 6 weeks, the average rate of gain will be cut in half, after which time there is usually a steady decrease in the rate of growth until no more gains are made.

Since there is more danger of trouble when the growth is relatively rapid, it is usually agreed that the greatest possibilities of trouble occur during the first period. If the chicks can be successfully reared to 2 months of age, the danger periods are generally passed.

ACTUAL GAINS. As far as actual gains are concerned, there will be some variation from period to period. There is a tendency, however, for the actual gains to increase until the chicks are about 3 months of age, after which time there is a general decrease.

FEED RELATIONS. The amount of food consumed increases with the increase in the size of the bird. Since the rate of growth is also rapid at the start, the gains per unit of food are larger

Period, Weeks	Pounds of Feed to Produce One Pound of Gain
0—4	2.42
4—8	3.80
9—12	6.30
13—16	7.10
17—20	8.51

early in life. A larger proportion of the food goes into growth. Hence more economical gains are made when the chicks are growing rapidly, as shown by the accompanying figures, which indicate, for a typical group of birds, the amounts of feed required to produce 1 pound of gain in Leghorn pullets at different ages.

EARLY HANDICAPS. A number of reports[5-7] have shown that depressed growth in earlier periods was compensated for later by more rapid growth, when the nutrient level became adequate. Where there is a partial deficiency, early growth may be slow. However, this growth may be made up in later periods so that, with the same breeding, the final mature weight of such chicks will be approximately the same as that of chicks which grew faster at the start, in which case later growth is relatively not so rapid. There is, however, also probably some level for the various nutrients below which one cannot safely feed because the resulting severe stunting can never be entirely overcome.

Parker[8] showed that a variety of early handicaps, including poisons, starvation, and high and low temperatures, failed to alter markedly the course of yolk absorption in baby chicks and also failed to produce permanent effects in body weights.

Mayhew[9] reported that chickens severely infected with coccidiosis at 12 or 13 weeks of age do not recover their loss in weight; that is, they do not become equal in weight to the controls during the following 9 to 10 weeks.

Several workers[10-12] concluded that retarding the growth of chicks resulted in a definite delaying of sexual maturity with variable effects upon body weight and egg production of the mature birds. Retarding of growth and maturity did not appear to be a sound economic practice, but it could be followed if desired without fear of permanent injury to the birds.

There are many advantages of securing early rapid growth (which is the normal condition), such as maintained vitality and body reserve, earlier broiler marketing, and sufficient weight of pullets at time of laying to produce good production and egg size. Titus and Jull[6] point out that, in the lots receiving skimmilk (and growing rapidly early), the point of inflection of the growth curve occurred earlier than in the lots not receiving it. This suggested to them that the more nearly a "perfect" condition of nutrition is approached, the more nearly will the whole of the growth curve approach the curve of diminishing increment, which they believe most nearly to fit the growth data of

chickens developing normally. Hendricks, Jull, and Titus[13] further suggest that the curve of diminishing increment may be of value in determining the suitability of a given feed for growth.

FEED REQUIREMENTS

An analysis of the bodies of chicks at various stages of growth will help to understand feed needs. The data in Table 21 are given by Halnan:[14]

TABLE 21. ANALYSIS OF CHICKS AT VARIOUS AGES

Age in Weeks	Ash, Grams	Protein, Grams	Energy, 100 Calories
1	1.04	6.9	0.7
3	3.02	17.2	1.7
7	9.53	45.4	3.4
11	17.3	84.0	6.2
15	45.5	223.5	14.8
20	64.8	282.8	20.5
24	90.0	338.0	24.4
28	94.0	376.0	32.1

AMOUNT OF FOOD. During the early stages, the rate of growth of the chick is limited by its capacity to consume food. Titus and Hendricks[15] conclude that if chicks are fed at different levels of feed intake (with a complete ration) up to about one pound, the average live weight of the chicks in all the pens could be considered as a function of feed consumption alone. A possible explanation of this is that the maintenance requirement of the young growing chick is only a small fraction of the total amount of feed consumed.

There is probably little possibility of overfeeding a chick in its early stages of growth if the ration is properly compounded. In order to get maximum food consumption, it is important to provide sufficient and proper feeding space. The Nutrition Council of the American Feed Manufacturers recommends the following feeding space as being satisfactory for 100 chicks:

Age in weeks	
1 day — 2 weeks	100 linear inches
3 — 6 weeks	175 linear inches
7 — 12 weeks	300 linear inches

The following drinking space is suggested:

1 day— 2 weeks	20 linear inches or two 1-gallon fountains
3—12 weeks	40 linear inches or two 3-gallon fountains

From the results obtained in various rearing experiments Axelsson[16] has calculated the total food requirements for maintenance and growth of "light," "medium," and "heavy" chicks at different ages (Table 22).

TABLE 22. FOOD REQUIREMENTS OF THE GROWING FOWL (POUNDS PER DAY PER 100 BIRDS)

Month of Life	Light Breeds		Medium Breeds		Heavy Breeds	
	Females	Males	Females	Males	Females	Males
1	4.4	4.7	4.7	4.9	4.9	5 1
2	8.6	9.3	9.1	10.0	9.8	10.7
3	12.6	13.8	14.2	15.6	15 4	16.8
4	16.1	17.7	17.9	20.3	20 0	22.4
5	18.2	20.3	21.0	23.5	24.0	26 3
6	18.9	21.4	21.9	25 4	24.9	29.1
7	18.6	21.0	22.4	26.1	27.5	30.5
8	....	....	21.7	25.6	27.5	30.5
9	....	....	....	. .	26.6	29 6

For additional information on the amount of food for young stock, see Chap. 19, "Economics of Feeding."

The best growth is induced by a ration having a balance of the essential nutrients. Any deficiency or defect in the diet which prevents normal development will also increase the variability in growth.[17]

PROTEIN. It has been pointed out by various investigators that the protein requirements of different species of animals are more or less proportionate to the rate of growth.

Bunge[18] also shows that the rate of growth is proportional to the protein in the natural food (milk), as indicated by the length of time required to double the initial weight (Table 23).

It has also been pointed out by various authorities that the protein requirements of chicks are greater than the protein needs of laying hens. The unabsorbed yolk material, present in the chick at the time of hatching, contains a large amount of protein. It has been stated that this ratio of protein to the other parts is about 1:1.4. When we consider the wild birds, we note that the young are fed very largely on grubs and worms, which are primarily protein.

Growth in chicks and the accompanying protein requirements

TABLE 23. RELATION IN MAMMALS OF GROWTH RATE TO PROTEIN OF MILK

Time for Newborn Animal to Double Its Weight		Milk Per Cent Protein	Milk Nutritive Ratio
Man	180 days	1.6	1:8.6
Horse	60	2.0	1:4.2
Cow	47	3.5	1:3.8
Goat	22	3.7	1:3.6
Sheep	15	4.9	1:3.4
Hog	14	6.1	1:3.0
Dog	9	9 7	1:2.5
Rabbit	6	15.5	1:1.5

may be divided into three periods. The first period, calling for rapid growth and a high protein level, includes approximately the first 6 weeks. The second period, during which growth is less rapid and the protein level can be decreased, extends from the end of the first period to about 3 months. The third period, during which growth is further decelerated and the protein level can be again decreased to some extent, continues from the end of the second period until the end of the growing period.

Funk[19] reports that when chicks were given free choice of food they selected a ration containing 18 to 19 per cent protein.

Most of the experimental results[20-30] indicate that the early rate of growth of chicks is increased as the protein level is increased to about 20 per cent, that lots receiving low-protein rations weigh less practically throughout, that mortality is usually increased in the low-protein lots, and that the protein can be decreased in the later periods. Some reports indicate higher levels[31] as being desirable or satisfactory from the standpoint of the health and well-being of the animal. Some trials[32] show that heavier breeds made more satisfactory gains when a higher level of protein was used.

ing, and cannibalism developing in low-protein pens as early as the second and third week. Feather eating and pick-outs were also observed in low-protein pens at Cornell. Tomhave[29] indicates a direct relationship between the number of bare-breasted birds and the level of protein. Gericke and Platt[33] indicated that feather development over the entire body showed a significant increase in direct relation to the amount of protein in the ration (10.4 to 15.4 per cent), and the development of each feather tract was of the same order. Carver and associates[20] and Zuzuki and

Hatano[24] report no influence of the protein level upon the development of liver, kidney, spleen, pancreas, heart, adrenal body, pituitary body, thymus gland, and testicles.

In work with experimental coccidiosis, Jones[34] states that chickens on high-protein diets maintained their weight at a level nearer that of their uninfected controls than chickens on a low-protein diet. High-protein diets may thus be considered to furnish a reserve that prevents undue loss of weight as a result of coccidial infection. Luttermoser and Allen[35] report that young chickens fed a diet containing 13 per cent protein and experimentally infected with the tapeworm (*Raillietina cesticillus*) gained less weight than their uninfected controls throughout the duration of a 6-week period, whereas the young chickens fed a diet containing 26 per cent protein and infected with the same number of cysticercoids did not differ markedly in weight from their uninfected controls.

Titus[36] reported that chicks made the greatest gain per pound of feed when the diet contained 21 per cent protein. On the basis of this level, the 20 per cent protein ration showed an efficiency of 99.7 per cent; the 19 per cent protein ration, 98.7 per cent; the 18 per cent protein ration, 97.2 per cent; and the 17 per cent protein ration, 94.6 per cent. The rations containing less than 17 per cent protein decreased very rapidly in efficiency The level of protein intake, so long as it is not less than about 13 per cent, has little effect on the maximum live weight ultimately attained. However, the time required to reach the maximum live weight is greatly increased as the level of protein intake decreases from 21 to 13 per cent.

The Delaware,[29] New Jersey,[37] and Washington[20] stations indicate that decreasing amounts of protein in the growing rations will meet the requirements which change with age

Titus[36] concludes that even though the optimum level of protein intake is, from the physiological standpoint, about 21 per cent, from the standpoint of economy it may be only 18 or 19 per cent, because the efficiency of feed utilization for growth is only slightly less at these levels. The difference in cost will be an important factor in determining the most economical level He has found it a good practice to feed a diet that contains 20 to 21 per cent of protein until the chickens are about 12 weeks old and then gradually decrease the protein content to 16 or 17 per cent by the time the pullets are ready to lay.

The results of all trials at Cornell[26] indicate that to obtain early rapid growth the ration should contain approximately 20

per cent protein during the first month. This amount can be reduced 2 per cent for each succeeding month. The indications also are that the ration should never contain much less than 15 per cent protein.

AMINO ACID REQUIREMENTS. Some of the amino acids are essential and must be present in the ration. Others can be synthesized by the chick. The essential amino acids can be supplied in minimum amounts only when there are sufficient dispensable amino acids present so that the essential ones are not used for their synthesis.

Considerable research has been reported concerning the quantitative amino acid requirements[38] of chickens. These requirements may be summarized as follows: arginine 1.2 per cent; glycine 1.0–1.5 per cent; isoleucine 0.5 per cent; leucine 1.5 per cent; lysine 0.67 to 1.0 per cent; methionine (with cystine present) 0.28 to 0.42 per cent; sulfur-bearing amino acids (methionine + cystine) 0.7 to 1.0 per cent; phenylalanine 1.6 per cent; threonine 0.45 to 0.6 per cent; tryptophan 0.18 to 0.5 per cent; valine 0.7 per cent.

FAT. It is not necessary to include fat in the ration for chicks since they can utilize carbohydrates for fat formation. However, there is some evidence that certain unsaturated fatty acids are needed in the diet.[39] Davis and Upp[40] reported that chicks fed a fat-free ration grew somewhat more slowly than the chicks receiving fat, but that the slight difference was overcome by the time the pullets reached maturity. Russell, Taylor, and Polskin[41] reported that the growth rate of chicks to 14 weeks of age fed a low-fat diet (0.1 per cent) was not significantly below that of chicks fed a normal ration (4.1 per cent fat). Chicks on the low-fat diet utilized crystalline carotene despite the very low level of fat intake.

In studying the tolerance of growing chicks for soybean oil in their ration, Henderson and Irwin[42] found that the mean weight of chicks at 8 weeks did not vary significantly until the ration contained 10 per cent of oil, after which a significant decrease in weight was obtained.

MINERALS. Calcium and phosphorus are the minerals of chief importance in chick rations. The result of research indicates that the minimum calcium requirement of chicks is 0.6 to 0.7 per cent of the ration in the presence of sufficient vitamin D. The minimum requirement for phosphorus[43] is 0.6 per cent of which 0.4 should be in the inorganic form. There is some indication that somewhat less is required for growth than for bone

calcification. The requirement also decreases somewhat with age.

Furthermore, the evidence indicates that these elements should be present in a satisfactory ratio and that they have an interrelationship with vitamin D.[44] The calcium-phosphorus ratio of the blood and bones is about 2 of calcium to 1 of phosphorus. In the chick ration it appears possible to extend this over a range of 1.0:1 to 2.5:1 without any striking upset in the normal blood picture or any marked retardation in growth. A *ratio of about 1.5:1 seems preferable.*

There is little experimental evidence to show exactly what are the upper levels of calcium and phosphorus, beyond which it is *unsafe to go. However, it would appear that 1.8 to 2.0* per cent of calcium and 0.9 to 1.0 per cent of phosphorus are probably the maximum levels it is wise to use in chick rations.

In order to prevent perosis, the ration should contain a *minimum* amount of 35 to 50 parts per million of manganese.[45] For an average ration the addition of 1/4 pound of manganese sulphate per ton will supply this amount.

The sodium and potassium requirements,[46] which vary with growth rate, have been reported as being 0.10 – 0.30 per cent for sodium and 0.23 – 0.40 per cent for potassium. The requirement for chloride is probably less than 0.6 per cent.

The iodine requirement[47] has been reported between 30 and 150 parts per billion; and the magnesium requirement[48] as 40 milligrams per 100 grams of feed.

Salt is usually added to most chick rations One quarter to one-half per cent is the most common recommendation

VITAMINS. The vitamin A requirement[49] of the chick ration has been reported as ranging from 150 to 350 International units of vitamin A per 100 grams of feed. The usual amounts of cod liver oil, 25 to 30 per cent of yellow corn, or green food will furnish this amount.

The vitamin B_1 requirement[50] of chicks has been reported as being 130 to 150 micrograms per 100 grams of feed. If the ration is made up of 30 per cent cereals, sufficient thiamine will *be supplied.*

If the birds are not exposed to direct sunshine, it will be necessary to feed them cod liver oil or some other vitamin D carrier. Twenty to twenty-five units per 100 grams of feed have been reported to prevent rickets, but approximately twice that amount are needed to give satisfactory growth.[51]

The amount of riboflavin needed by the chick will depend upon

its age.[52] The first two weeks it will be 300 to 350 micrograms per 100 grams of feed, which will decrease to 100 micrograms per 100 grams after 2 months of age. When fed a constant amount, chicks needed approximately 290 micrograms per 100 grams of feed in order to attain normal weight at 8 weeks of age. Less riboflavin is needed to prevent curled-toe paralysis than for growth.

The pantothenic acid requirement[53-55] of chicks has been reported as ranging from 500 to 550 micrograms of pantothenic acid per 100 grams of diet. Less is needed for the prevention of dermatosis than for maximum growth. Rhode Island Reds were found less susceptible to pantothenic acid deficiency than Leghorns. Usually there will not be a pantothenic acid deficiency in practice since normal, commercial chick diets were shown to contain 1300 to 1700 micrograms of pantothenic acid per 100 grams.

The amount of vitamin B_6 (pyridoxine)[56-58] required by baby chicks has been variously reported as being 200 to 500 micrograms per 100 grams of ration.

Biotin has also been found necessary in the chick ration to prevent a typical dermatitis and promote growth in chicks. Hegsted and coworkers[59] report that the biotin requirement of the chick is at least 7 to 10 micrograms per 100 grams of the ration.

The choline[60] requirement of diets for chicks has been reported as being 0.1 per cent. This amount, however, may be influenced to some extent by the amount of methionine and betaine in the ration.

The niacin[61] requirement of chicks has been reported as being 8 to 13.5 milligrams per 100 grams. The variation can be accounted for in part by the tryptophan in the diet since this amino acid can be converted to niacin. The requirement for older chicks is considerably lower.[62]

The folic acid requirement of chicks as reported from Cornell[63] is indicated as 25 micrograms per 100 grams of diet for survival, 45 micrograms for growth and hemoglobin formation, and 55 micrograms for good feathering.

The vitamin B_{12}[64] requirement of the chick has been variously reported as ranging from 0.15 to 2.7 micrograms per 100 grams of ration. This great variation can be largely accounted for by the store of vitamin B_{12} in the chick at hatching. The higher values will apply to chicks hatched from eggs produced by hens on a diet deficient in vitamin B_{12}.

Normal blood-clotting time[65] was obtained by adding 1 per cent of alfalfa meal or 5 milligrams of menadione (vitamin K) per kilogram.

Other vitamins have been reported as being essential for normal chick growth, but information is lacking concerning quantitative requirements or the values of *feeds in respect to* them.

FIBER. Because fiber is not digestible, it is usually felt that the fiber content of chick rations should not be too high, especially since the bulk may decrease available food nutrients and particularly energy. Good results have been obtained with rations containing widely varying amounts of fiber. As an example, *the Oklahoma Station*[66] *reports no effect* on the growth or health of the chicks, up to 20 weeks of age, that could be attributed to the amount of fiber in rations containing 3.84 to 10.29 of fiber. Feather picking was worse in the low-fiber lots. Increasing amounts of fiber results in poorer gain and poorer efficiency of *the feed. On the other hand, the Kentucky Station*[67] *concluded* that maximum growth was obtained on rations containing approximately 5 per cent or less fiber from any source

Increasing the amount of such ingredients[68] as oats, barley, wheat middlings, and wheat bran has depressed growth and efficiency *of feed utilization.*

A requirement for chicks of 800–850 calories of available energy per pound of diet has been reported.[69-71] On the other hand, Hill and Dansky[72] found that Red-Rock crossbred chicks grew well on a ration containing 510 calories. However, their *feed* intake was greatly increased, and the greatest fat deposition was obtained on the ration containing 985 calories per pound. It appears that the available energy requirement for growth can be stated to be about 850–1000 calories per pound

STANDARDS. Until recently very little information was available *concerning standards* for requirements for young stock. The standard, as given by W P Wheeler of the New York (Geneva) Experiment Station, was an early attempt to indicate the digestible nutrients required per day for each 100 pounds of live weight (Table 24).

SUMMARY OF NUTRIENT REQUIREMENTS FOR CHICKS

Having considered all the evidence to date, the Committee on Animal Nutrition of the National Research Council[73] suggests the amounts given in the table on page 362 as desirable standards

TABLE 24. WHEELER'S STANDARDS FOR RATIONS FOR CHICKS

	Total Dry Matter	Ash	Protein	Carbohydrates	Fats	Fuel Value	Nutritive Ratio
For the first two weeks	10.1	0.5	2.0	7.2	0.4	18,800	1:4.1
At 2 to 4 weeks of age	9.6	0.7	2.2	6.2	0.5	17,730	1:3.4
At 4 to 6 weeks of age	8.6	0.6	2.0	5.6	0.4	15,640	1:3.3
At 6 to 8 weeks of age	7.4	0.5	1.6	4.9	0.4	13,780	1:3.7
At 8 to 10 weeks of age	6.4	0.5	1.2	4.4	0.3	11,680	1:4.3
At 10 to 12 weeks of age	5.4	0.4	1.0	3.7	0.3	10,000	1:4.4

for the probable dietary requirements of growing chicks. The figures do not include margins of safety to compensate for possible losses of vitamins during feed processing, transportation, and storage and for variations in feed composition and in environment. In earlier reports the National Research Council suggested allowances which included margins of safety of 66 per cent for vitamin A, 50 per cent for vitamin D, and 20 per cent for the water-soluble vitamins.

THE RATION

The successful rations are made up of a combination of cereals and animal protein concentrates. Quality of protein is supplied by the use of milk, meat scraps, fish products, and soybean oil meal.

For chick growth and well-being, the ration must supply the necessary vitamins. Vitamin A is supplied mainly in the yellow corn and alfalfa meal, and in fish oil when fed. Vitamin B occurs in the various cereals. Vitamin D is provided by fish oils and activated animal sterol, or exposure to sunshine. Riboflavin is furnished by milk products and fermentation by-products. Vitamin B_{12} is supplied by feeds of animal origin and fermentation by-products.

Calcium and phosphorus are the minerals needed in largest amounts. Where reasonable amounts of animal protein feeds are used, sufficient phosphorus is present. Calcium, however, is usually low and is provided by adding some calcium carrier such as pulverized limestone or oystershells.

Those feeds which are processed the least and which represent more nearly the whole product are safest to use. The feed

REQUIREMENTS* OF YOUNG CHICKENS

	Starting Chickens, 0–8 weeks	Growing Chickens, 8–18 weeks
Total protein, %	20	16
Vitamins		
Vitamin A activity (U.S.P. units)†	1200	1200
Vitamin D, (I.C.U.)‡	90	90
Thiamine chloride hydrochloride, mg.	0.8	?
Riboflavin, mg	1.3	0.8
Pantothenic acid, mg.	4.2	4.2
Niacin, mg.	12.0	?
Pyridoxine, mg.	1.3	?
Biotin, mg.	0.04	?
Choline chloride, mg.	600	?
Folacin, mg.	0.25	?
Minerals		
Calcium, per cent	1 0	1 0
Phosphorus, per cent§	0 6	0 6
Salt, per cent ‖	0 5	0.5
Potassium, per cent	0.2	0 16
Manganese, mg.	25	?
Iodine, mg.	0.5	0 2
Magnesium, mg.	220	?
Amino acids, %		
Arginine	1 2	—
Lysine	0.9	—
Histidine	0 15	—
Methionine	0 8	—
or		
Methionine¶	0.45	—
Cystine	0 35	—
Tryptophan	0 2	—
Glycine**	1 0	—
Phenylalanine	1.6	—
or		
Phenylalanine††	0.9	—
Tyrosine	0 7	—
Leucine	1 4	—
Isoleucine	0 6	—
Threonine	0 6	—
Valine	0 8	—

* In percentage or amount per pound of feed

† May be fish oil vitamin A or pro-vitamin A from vegetable sources

‡ International chick units.

§ At least 0.45 per cent of the total feed of starting chickens should be inorganic phosphorus. All the phosphorus of non-vegetable feed ingredients is considered to be inorganic Approximately 30 per cent of the phosphorus of vegetable products is nonphytin phosphorus and may

must not be too bulky, or the actual food intake will be restricted, depressing growth.

It is not necessary to use very complex rations for satisfactory results.[74] On the other hand, it is not safe to restrict the ration to too few feeds. The Nebraska Experiment Station[75] reports a significantly greater rate of gain in weight and retention of nitrogen, calcium, and phosphorus on a mixed concentrate consisting of meat scraps, fish meal, and dried buttermilk than on a single supplement of meat scraps.

To meet the requirements for chick rations the suggested formula patterns are tabulated on the next page.

FEEDING MANAGEMENT

TIME OF FIRST FEED. When should chicks receive their first feed? It was noted early that the chick absorbed the unused yolk just before hatching time. The unused part of the egg, as reported by Tangl,[76] represents 48 per cent of the original energy in the egg. It is found largely in the abdomen of the chick and is absorbed during the early days of life. This energy is sufficient to maintain the body temperature of chicks for 72

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be considered as part of the inorganic phosphorus required. A portion of the phosphorus requirement of growing chickens must also be supplied in inorganic form. For these birds the requirement for inorganic phosphorus is lower and not as well defined as in the case of starting chickens.

‖ This figure represents added salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content.

¶ Cystine will replace methionine as long as the ration contains not less than 0.45 per cent methionine.

** The chick can synthesize glycine, but the synthesis does not proceed at a rate sufficient for maximum growth.

†† Tyrosine will replace phenylalanine as long as the ration contains not less than 0.9 per cent phenylalanine.

TENTATIVE REQUIREMENTS FOR CERTAIN VITAMINS AND MINERALS, 0–8 WEEKS

	mg. per lb.
Vitamin B_{12}	0.004
Vitamin K	0.18
Iron	9.0
Copper	0.9

hours or more. It was, therefore, believed that chicks should not be fed before this time, since the introduction of food would prevent or delay the absorption of the yolk and cause trouble by overloading the digestive system. However, it was shown later that the assimilation of the yolk is a fairly stable and regular process from day to day, influenced only slightly by feeding.[8, 77]

The next question is whether there is any advantage in feeding early or late. The yolk is not largely absorbed until the chicks

RECOMMENDED FORMULA PATTERNS FOR CHICK MASHES

Ingredients	Starter (all-mash)	Growers (with grain) Confinement	Pasture
	lb./ton	lb./ton	lb./ton
High-energy grain products (corn, wheat, wheat red dog flour, milo, oatmeal)	900 +	700 +	500 +
Medium- and low-energy grain products (oats, barley, wheat flour middlings, standard middlings, bran)	0-400	0-600	0-800
Vegetable proteins (soybean meal, corn gluten meal, peanut meal)	300-400	350-450	400-500
Animal proteins; minimum levels (fish meal, fish solubles, meat scraps)	50-100	50-100	—
Other B-vitamin carriers (dried milk products, dried yeast, dried distillers' solubles, fermentation solubles)	100	100	—
Dehydrated alfalfa meal	50-100	100	—
Additional riboflavin* (if needed)	+	+	—
Additional vitamin B_{12}* (if needed)	+	+	—
Additional vitamin A* (if needed)	+	+	—
Vitamin D_3 (feeding oils or D-activated animal sterols)	+	+	—
Calcium and phosphorus supplements (steamed bone meal, dicalcium phosphate, defluorinated phosphate, limestone)	30-50	60-80	80-100
Salt	5	10	20
Manganese sulfate (65% feeding grade)	0 4	0 5	0 5
Antibiotic feed supplement	+	±	±

* Refers to the use of riboflavin supplements, vitamin B_{12} supplements, and vitamin A sources of guaranteed vitamin content or other vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients

REQUIRED COMPOSITION OF CHICK MASHES

Nutrient	Starter (all-mash)	Growers (with grain) Confinement	Pasture
Protein, %	20	20	20
Calcium, %	1-1.4	1.5-2*	1.5-2*
Phosphorus			
Total %	0.6	0.9	0.9
Available %	0.4	0.7	0.7
Vitamin A,† I.U./lb.	2000	4000	—
Vitamin D, I.C.U./lb.	135	270	—
Riboflavin, mg./lb.	1.6	1.3	—
Vitamin B_{12},‡ mg./lb.	1.5-2	1.5-2	—

* Free choice feeding of oystershell or other calcium supplement recommended since this level of calcium will not meet full requirements.

† If corn constitutes half of scratch grain mixture for growing chicks the level of vitamin A in the mash can be reduced by 1000 I.U./lb.

‡ Refers to vitamin B_{12} supplied by fish products, meat scrap and vitamin B_{12} supplements.

are about a week old. Deaths from starvation begin in about 5 days. It has been shown by many workers[8, 77, 78] that early feeding is not harmful. Some of these tests indicate that early mortality is greater in the lots where feed is withheld, the rate of mortality increasing as feeding time is delayed. Later mortality does not seem to be affected. Too great periods of starvation will cause the chicks to pick up litter to satisfy the hunger craving, with resultant impaction in the crop.

It is probably safe to say that the chicks can have food as soon as they want it, a problem of feeding not to be confused with brooding management. For example, some authorities recommend removing chicks from the incubator and confining them in chick boxes for 24 hours or more, not to keep the chicks from eating but to insure against their getting chilled or overheated during this critical period. If the chicks are placed in the brooder houses, they should be kept near the hover and should have feed and drink available. Frequently milk is given as a drink for the first day or two. It serves both as drink and food.

In general, it would seem that chicks may be fed as soon after hatching as they care to eat, with no harmful results upon weight or mortality. Furthermore, it is well to feed them not later than 36 to 48 hours after hatching.[79] The fact that chicks will go for much longer periods before receiving their first feed should be

looked upon as a fortunate curcumstance, which permits shipping chicks long distances, rather than as the correct time to feed them.

FEEDING METHODS. During recent years there has been a general tendency to feed chicks all-mash rations. They are also fed grain-mash rations and modified rations, in which the all-mash is used as a starting mash and later grain is fed. About equally favorable results can be obtained from grain-mash rations, all-mash rations, and modifications of the two systems, if the nutrients are properly provided (Table 25).

TABLE 25. GROWTH OF CHICKENS BY DIFFERENT METHODS OF FEEDING AND RESULTING PRODUCTION DURING THE FIRST LAYING YEAR (CORNELL EXPERIMENT STATION)

	Lot 1	Lot 2	Lot 3
	All Mash to 8 Weeks. Grain and Mash After 8 Weeks	Grain and Mash from the Start	All Mash to 26 Weeks
Av. wt. of pullets			
4 weeks	178 grams	162 grams	177 grams
8	496	463	492
12	777	764	782
24	1526	1519	1495
Feed per bird to 26 weeks	23.4 lb	23.1 lb.	23.8 lb
Date of first egg	Aug 31	Aug 30	Aug 19
Eggs: Aug	. .		0.2
Sept	3.0	3.5	2.4
to Oct. 6	1.2	1.7	1.0
	4.2	5.2	3.6

Pullets were placed in laying houses at 26 weeks and put on a grain-mash ration.

	Lot 1	Lot 2	Lot 3
Number at start	32	44	49
Died during year	7 (22%)	10 (23%)	8 (16%)
Culled during year	4	2	1
Completed year	*21 (66%)*	*32 (73%)*	*40 (82%)*
Average first year egg production	231	225	233

Up to six weeks Lot 3 was fed the same ration as Lot 1 For 6 to 12 weeks 10% meat scrap and 5% milk were used (5% meat scrap being omitted) After 12 weeks 5% milk and 5% meat scrap were fed All received the Cornell Laying Ration after 26 weeks.

As already indicated, the growth of the chick varies with age. During the early periods, when growth is rapid, there is a greater requirement for protein, minerals, and vitamins. Excesses may or may not be detrimental but are usually not economical. Therefore, when all-mash or grain-mash rations are fed, it is desirable, if not necessary, to have two or three different mixtures to cover the growing period.

The modified system, such as the Cornell ration, permits a single mixture for both a starting and growing mash. The mash is fed as an all-mash ration for about 4 to 8 weeks. At that time grain is introduced and is consumed by the birds in increasing quantities, thus automatically reducing the protein of the ration in the later periods.

FEEDING GROWING PULLETS. The pullets must not suffer any setbacks during the summer. Some of the things to be watched are the green food supply, water, and amounts of grain consumed. They must have an adequate and complete ration at all times.

FEEDING COCKERELS. Cockerels that are kept for future breeders should be given exactly the same care and attention as the pullets. Put them on a separate range, where they will get the same opportunities for range and outdoor conditions, the same feeds, and the same methods as the pullets.

FEEDING BROILERS. The terms "broiler" and "fryer" are now used synonymously and refer to a 10- to 12-week old chicken weighing 3 to 4 pounds (Table 26). In broiler production it is necessary to take advantage of the early rapid growth of

TABLE 26. GROWTH RATE AND FEED CONSUMPTION OF HEAVY BREED BROILERS AT CORNELL UNIVERSITY

Age in Weeks	Average Weight, lb	Total Feed Consumed, lb
1	.19	.17
2	.37	.50
3	.60	99
4	.91	1.68
5	1.23	2.52
6	1.61	3.50
7	2.01	1.63
8	2.44	5.78
9	2.87	7.22
10	3.29	8.66
12	3.99	11.96

chicks. This produces tender meat and efficient feed utilization.

Rapid growth can best be obtained on rations containing higher levels of protein.[80] Most of the experimental results indicate a level of 20–21% of protein as being satisfactory. Almquist and Asmundson[81] report that Single Comb White Leghorn cockerels grew more rapidly during the first week on a 30 per cent protein mash, as compared with a 20 per cent mash, and maintained their advantage in weight up to 8 weeks of age. Receipts over feed cost per bird were increased by starting the broilers on the high-protein mash when the high-protein mash was fed for not more than 4 weeks. Other reports,[82] however, show no advantage of starting chicks on high-protein diets provided they contain all the necessary amino acids, vitamins, and other nutrients in sufficient amount and in proper balance.

Antibiotics have been shown to stimulate early growth and to improve feed efficiency. The growth response of supplementary methionine[83] has been variable, but it has generally improved feed efficiency. The various nutrients as indicated for growth must also be supplied.

Since the efficiency of a ration is related to its energy value, emphasis has been placed on high-energy rations for boiler production. Hence the ration must be made up of cereal grains and grain products of high-productive energy value. High-energy rations will produce birds with a high-quality carcass carrying a sufficiently high-fat content for good finish and pigmentation High-energy rations have also been reported as producing birds that will lose less weight in transit to market.[84] High-energy ration fed stock has also yielded higher weight returns in cooked form with both the fast- and the slow-cooking methods.[85]

All-mash rations are generally used for broilers. However, it is possible to feed some grain with these rations during the final 2 or 3 weeks of the broiler production period The Arkansas Station[86] reported the best gains for broilers where the starter mash was fed throughout a period of 12 weeks but where the chicks had access to a scratch ration of whole wheat and medium corn chops during the last 6 weeks.

The use of artificial illumination to provide a 14-hour day and the feeding of wet mash or pellets are means of speeding up growth by increasing food consumption.

Since appearance is an important consideration in marketing broilers, it is advisable to include feeds in the broiler rations which will produce deeper pigmentation, such as yellow corn, corn gluten meal, and alfalfa meal.

Cod liver oil should not be used in the broiler ration the last 2 weeks before marketing, as the flesh might be tainted with a fishy odor or taste.

To meet the requirements for broiler rations the tabulated formula patterns are suggested on p. 370.

COCCIDIOSIS RATION. A common former recommendation for the treatment of coccidiosis was the so-called milk flush. The milk-sugar, changing to acid in the chicks' intestines, and the excessive amount of water consumed seemed to clear the chicks' digestive tracts quite effectively.

At the present time coccidiosis is more commonly controlled by the means of sulfa drugs which are fed both prophylactically and therapeutically.

FALL MANAGEMENT OF PULLETS. Pullets should be well developed in body before they start to lay. It is important that pullets be in good condition with a surplus of body fat when they commence to lay if they are to withstand the demands of heavy laying. To do this a common practice is to feed heavily on grain in the fall. It is a mistake, however, to feed pullets wholly on grain as they approach maturity unless special adjustment has been made, for this slows up complete development. Mash should always be fed along with scratch grain, as the mash is more complete in protein, minerals, and vitamins than the scratch grain. The combination of the two furnishes the birds a more complete assortment of food elements at the time they are finishing their development.

Some poultrymen have a very definite impression that the time at which the birds begin to lay can be decidedly regulated by the amount of protein, and particularly animal protein, furnished to the pullets the last month or 6 weeks, and in come cases only 2 or 3 weeks, before those birds come into production. It is doubtful whether one can influence the age of sexual maturity of pullets unless one feeds below the necessary amount of protein, in which case growth is delayed.

Results at Washington[20] indicate that the higher protein levels affect the rate of sexual maturity. The difference between the extremes was about 40 days. The slower-maturing pullets on the low-protein levels also laid the larger eggs. This is probably true because egg size is closely correlated with age. On the other hand, a number of stations[21-24, 26, 87, 88] indicate that liberal protein feeding during growth did not materially affect age of sexual maturity. The Oklahoma Station[25] states that more time is required to reach sexual maturity with rations under 16

RECOMMENDED FORMULA PATTERNS FOR BROILER MASHES

Ingredients	Broiler Starter, lb/ton	All-Mash grower, lb/ton	Mash-Grain* grower lb/ton
High energy grain products (corn, wheat, red dog flour, milo)	900 +	1000 +	900 +
Medium energy grain products (oats, barley, wheat flour middlings)	0-300†	0-300†	0-300†
Vegetable proteins (soybean meal, corn gluten meal, peanut meal)	400-550	300-450	400-550
Animal proteins: minimum levels (fish meal, fish solubles, meat scraps)	50-100	50-100	50-100
Other B-vitamin carriers (Dried milk products, distillers' dried solubles, fermentation solubles, dried yeast)	100	50	100
Alfalfa meal (minimum 17% protein)	50	50	50
‡Additional riboflavin (if needed)	+	+	+
‡Additional vitamin B_{12} (if needed)	+	+	+
‡Additional vitamin A (if needed)	+	+	+
Vitamin D_3 (feeding oils or D-activated animal sterols)	+	+	+
Calcium and phosphorus supplements (steamed bonemeal, dicalcium phosphate, defluorinated phosphate, limestone)	20-60	20-60	30-60
Salt	5	5	10
Manganese sulfate (70% feeding grade)	0 5	0.5	1
Antibiotic feed supplement	+	+	+
Required nutrient levels of mash mixtures:§			
Protein, %	20	17.5	21
Calcium, %	1-1 4†	1-1 4†	1 6-2 0†
Phosphorus, total %	0 6-0.8†	0.6-0 8†	0 9-1 1†
Phosphorus, available %	0 4	0.4	0 7
Vitamin A, USP units/lb.	2000	2000	4000
Vitamin D, I.C.U./lb.	135	135	270
Riboflavin, mg/lb.	1 6	1.6	2 7
Vitamin B_{12}, μg/lb.	2	2	4
Niacin, mg/lb.	12	?	?
Pantothenic acid, mg/lb.	4.5	?	?
Productive energy, cal/lb	850	900	800

* Formulated for use with feeding rates 60% mash and 40% grain

† Higher figure is maximum recommended level

‡ Refers to the use of riboflavin supplements, vitamin B_{12} supplements, and vitamin A sources of guaranteed vitamin content or other

per cent protein but that there is no difference in weight at maturity (10 months of age). Results at the Iowa Station[89] suggest that egg weight may be dependent on size or capacity of body or oviduct instead of body weight. In that event the most rapid attainment of maximum egg size by pullets in the autumn might be expected from rations which stimulate rapid growth of body framework, and hence "fattening" rations may delay the attainment of maximum egg size.

If the age at which birds come into production is to be influenced to any extent, it can be done only by reducing the protein 2 months or more before the birds begin to lay, in which case growth will be materially delayed. This is a questionable practice.

It is not advisable to "hold back" pullets in the fall. Early laying is an inherited factor controlled primarily by breeding. Time of laying can be influenced only a few weeks by feeding. The best all-round results are obtained when the birds are so managed that they can be kept growing continually and come into production normally.

In general, one can say that a considerable range in the protein level of the growing ration is possible and still obtain satisfactory growth. Egg size is related to some extent to body weight but to a greater degree to age of sexual maturity. With a sufficiency of the various nutritive factors, higher protein rations are not harmful and are to be preferred to low-protein rations which will retard growth. Since both breeding and feeding have an influence upon growth, sexual maturity, and egg size, it is necessary to consider the effect of both and to synchronize the breeding and feeding factors. For example, birds that have been bred to lay at 5 months should be fed to produce body growth as rapidly as possible in order to have them ready to lay at that time, rather than to try to hold back their development in the hope that sexual maturity can be delayed.

For those pullets that are still immature, owing to late hatching, slow development, or unfavorable rearing, the growing rations will need to be continued. It might even be necessary to introduce wet mashes or other measures to increase food consumption. If the short days still find them unprepared for pro-

vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients.

§ Estimates of required nutrient levels are based largely on the recommendations of the National Research Council Committee on Animal Nutrition.

duction, the days can well be lengthened by the use of artificial illumination.

CONFINEMENT AND BATTERY REARING. *Where the chicks are reared in confinement and in batteries, it is especially essential that the ration be complete and correct in all respects since the chicks must depend entirely upon the feed given them. Chicks on range can succeed on rations that are not complete since they can supplement them with sunshine, green plant material, and other protective and nutritious substances.*

CHICK RATIONS

It is possible to formulate many chick rations that will meet the requirements and hence be satisfactory. A number of recommended rations for growing chickens will be found in the Appendix. (See page 528.)

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CHAPTER 13

FEEDING AND MANAGEMENT FOR EGG PRODUCTION

Considerable variation is found in the rations that are used for egg production and the methods of feeding them. However, there are certain requirements that are met by all successful rations. Even though many apparent changes in feeding practices have occurred during the past few years, the principles have not changed to any extent.[1]

FEED REQUIREMENTS FOR EGG PRODUCTION

The amount of feed required by fowls is dependent upon the size of the bird, the number of eggs laid, the size of the eggs, increase in weight, and variations in maintenance needs, as influenced by activity, temperature, and the like.

PROTEIN. Satisfactory production cannot be obtained unless additional protein, besides that found in grains, is supplied.[2]

Halnan[3] made the accompanying estimates of the protein and energy requirements of a laying hen.

Hens in production require a continuous supply of protein since the nitrogen required for egg production is largely, if not

FOR GROWTH AND MAINTENANCE (PULLETS)
PER BIRD PER DAY

Weight of Bird (in lb.)	Digestible Protein (in grams)	*Starch Equivalent* (in grams)
3	6.5	51 7
4	7.4	58.1
5	8 3	64.1
6	9.2	69 7
7	10.1	75.0
8	11.0	80 0
For the Production of a 2-oz.* Egg		
	15 0	40 0

* (28.35 grams = 1 oz.)

entirely, drawn from the food.[4] An insufficient amount of protein will result in decreased egg production, lower body weight, and smaller egg size. A shortage of albumin in the ration has been reported as resulting in pickouts which ceased directly after albumin had been fed.[5]

Where birds were given the opportunity of balancing their own ration,[6,7] some birds laid well and gained on a 12 to 13 per cent protein level while others wanted or required a higher level. Non-laying birds thrived and prepared to lay on an 11 per cent protein ration. In general, egg production was in accordance with the protein level, but the highest levels were not always the most economical.

Experimental results[8-15] generally show that a ration containing 12 per cent protein was not sufficient for satisfactory egg production, body weight, or egg size; that the 14 per cent protein ration gave satisfactory egg production but did not maintain body weight at all times and was not conducive to best egg size: that the 16 per cent protein ration was satisfactory in all respects.

Workers in the United States Department of Agriculture[16] report that increasing the percentage of protein in the diet, within the limits of 11.2 per cent and 23.6 per cent by the use of protein supplements of different origin, augmented egg production (1) by increasing intensity of production, (2) by increasing egg weight through direct effect on yolk weight, and (3) indirectly by increasing body weight and yolk weight, thereby increasing albumen weight. Increasing the protein level, within the limits stated, increased the quantity of egg produced per unit weight of feed eaten. Increasing the protein content decreased the efficiency of protein for egg production.

In studying the relationship of ruptured yolk to fowl paralysis, Moore[17] reports that results over a period of 3 years indicate higher mortality from a flock receiving a 13.5 per cent protein ration than from one receiving an 18.5 per cent protein diet. Bronkhorst[18] reports higher mortality due to prolapse from pullets on a basal mash containing 10 per cent of meat meal than from pullets fed mixtures containing 15 and 20 per cent of meat meal. Prolapse was frequently followed by cannibalism and did not appear to be influenced by egg size, egg yield, or age at sexual maturity.

Byerly[19] suggests, as a result of food requirement studies, that possibly smaller birds require a higher percentage of crude protein in the diet than larger birds, for the same degree of production.

The question might arise concerning a possibility of feeding an excess of protein. The Western Washington Station[20] states that all-mash rations containing 30 per cent of a protein concentrate did not produce a high percentage of organic trouble. It would appear from this, as well as from the experience of others, that hens can tolerate a fairly high protein ration if other conditions are favorable.

As a general summary, it would seem that in order to promote satisfactory production, maintain body weight, and secure good egg size, the ration should contain 15 to 16 per cent of protein. Part of this should come from animal source. If the birds are on good range, favorable results can be obtained with a lower amount of protein in the ration.

AMINO ACID REQUIREMENTS.[21] The requirements of some of the essential amino acids for laying hens have been reported as follows: tryptophan, 0.15 per cent; lysine, 0 52 per cent; leucine, 1.35 per cent; sulfur-bearing amino acids, 0.53 to 0.63 per cent with a minimum of 0.28 per cent for methionine.

FAT. It has been shown that fat, as such, in the diet is not essential since it can be synthesized from the carbohydrates of the ration. Russell and coworkers[22] concluded that the reduction of the fat content of the ration to 1.56 per cent of fat was not deleterious to the performance of laying and breeding flocks. Although the hen on a low-fat ration was not able to absorb carotene as efficiently as on a normal ration, vitamin A was absorbed equally well on a normal or on a low-fat ration.

Heywang and Titus[23] found no difference in egg production, yolk weight, or live weight between pullets being fed a diet of low fat content and pullets being fed diets containing 4 per cent of coconut oil, palm oil, peanut oil, cottonseed oil, soybean oil, or hempseed oil. Heywang[24] reported slightly lowered egg production from pullets receiving 8 per cent of corn oil in their diet. The pullets receiving 2, 4, or 8 per cent of corn oil in their diet maintained a heavier average weight than those receiving the basal diet of low fat content. No statistically significant differences in hatchability that could be attributed to the differences in fat content of the diets were observed.

MINERALS. Calcium and phosphorus[25] are the two minerals needed in largest amounts. Both egg production and shell strength are decreased by deficiencies of calcium and vitamin D. Experiments at Cornell indicated 1.65 per cent of calcium as being sufficient. The minimum phosphorus requirement is 0.6 per cent of which 0.4 to 0.45 per cent should be inorganic.

The manganese[26] requirement for egg production is very low. More is required for hatchability. Forty to fifty parts per million of the feed will satisfy both needs.

VITAMINS. From the results reported on vitamin A[27] requirements it would appear that a ration containing a minimum of 2000 to 2250 International units of vitamin A per pound will give normal results. A ration containing 35 per cent of yellow corn and 2½ per cent of alfalfa will supply this amount.

If the birds do not get the benefit of direct sunshine, it will be necessary to supply vitamin D in the ration. About 250 International units of vitamin D per pound of feed are essential.[28] It can be furnished by the use of fish oils or activated animal sterols.

The riboflavin[29] requirement for layers is relatively low, being less than 130 micrograms per 100 grams of feed. The amounts found in ordinary rations seem to be sufficient. However, higher levels[30] appear to be required for hens in batteries.

The pantothenic acid[31] requirement for hens for satisfactory egg production and weight maintenance is not more than 150 micrograms per 100 grams of ration.

The folic acid[32] requirement for egg production is not as large as that for hatchability. It appears to be approximately 25 micrograms per 100 grams of ration.

The pyridoxine[33] requirement for laying hens has been reported as being 2 milligrams per kilogram of ration.

FIBER. Not much is known of the optimum fiber content of the ration. However, it is known that very little fiber, if any, is digested by poultry. Hence it is desirable that the amount be restricted. Also high fiber rations are lower in energy Production does not appear to be influenced by some increase in fiber,[34] probably because of an increase in feed consumption The weight of birds, however, might be affected. Bird and Whitson[35] reported that a level of 5.89 per cent of fiber in a laying mash exerted a detrimental effect on efficiency of feed utilization but not on egg production High efficiency rations are favored for layers Hill[36] places the energy requirement at 900 calories per pound.

DIETARY REQUIREMENTS

As a summary of all evidence to date, the dietary requirements or standards for layers are indicated by the Committee on Animal Nutrition of the National Research Council[37] as given

REQUIREMENTS* OF LAYING HENS

Total protein, %	15
Vitamins	
Vitamin A activity (U.S.P. units)†	2000
Vitamin D (I.C.U.)‡	225
Riboflavin, mg.	1.0
Pantothenic acid, mg.	2.1
Pyridoxine, mg.	1.3
Folacin, mg.	0.11
Minerals	
Calcium, %	2.25§
Phosphorus, %‖	0.6
Salt, %¶	0.5
Iodine, mg.	0.2
Amino acids, %	
Lysine	0.5
Methionine	0.53
or	
Methionine**	0.28
Cystine	0.25
Tryptophan	0.15

*In percentage or amount per pound of feed.

†May be fish oil vitamin A or pro-vitamin A from vegetable sources.

‡International chick units.

§This amount of calcium need not be incorporated in the mixed feed inasmuch as calcium supplements fed free choice are considered as part of the ration.

‖A portion of the phosphorus requirement must be supplied in inorganic form. All the phosphorus of nonvegetable feed ingredients is considered to be inorganic. Approximately 30 per cent of the phosphorus of vegetable products is nonphytin phosphorus and may be considered as part of the inorganic phosphorus required.

¶This figure represents added salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content.

**Cystine will replace methionine as long as the ration contains not less than 0.28 per cent methionine.

in the accompanying tabulation. The figures do not include margins of safety to compensate for possible losses of vitamins during feed processing, transportation, and storage and for variations in feed composition and environment. In earlier reports the National Research Council suggested allowances which included margins of safety of 66 per cent for vitamin A, 50 per cent for vitamin D, and 20 per cent for the water-soluble vitamins.

To meet the requirements for a laying ration, the tabulated

formula pattern is suggested for a laying mash (to be fed with grain).

AMOUNT OF FEED. Besides having a proper proportion or balance of nutrients, it is essential that the birds consume enough food. Mature fowls (not laying) eat less in proportion to live weight than younger fowls (not laying). Larger animals will

RECOMMENDED FORMULA PATTERN FOR LAYING MASH

	lb./ton
High-energy grain products (corn, wheat, wheat red dog flour, milo, oatmeal)	500 +
Medium- and low-energy grain products (oats, barley, wheat flour middlings, standard middlings, bran)	0–800
Vegetable proteins (soybean meal, corn gluten meal, peanut meal) } Animal proteins; (fish meal, fish solubles, meat scraps) }	400–500
Dehydrated alfalfa meal	100–150
Additional riboflavin* (if needed)	+
Additional vitamin A* (if needed)	+
Vitamin D_3 (feeding oils or D-activated animal sterols)	+
Calcium and phosphorus supplements (steamed bonemeal, dicalcium phosphate, defluorinated phosphate, limestone)	100
Salt	20
Manganese sulfate (65% feeding grade)	0 5

*Refers to the use of riboflavin supplements and vitamin A sources of guaranteed vitamin content or other vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients.

REQUIRED COMPOSITION

Protein, %	20
Calcium, %	2–2.5*
Phosphorus	
Total %	1.2
Available %†	0.8
Vitamin A,‡ I.U./lb.	6600
Vitamin D, I.C.U./lb.	680
Riboflavin, mg./lb.	1.3

*Free choice feeding of oyster shell or other calcium supplement recommended since this level of calcium will not meet full requirements.

†Approximately 30 per cent of the phosphorus of vegetable products is non-phytin phosphorus and may be considered as part of the inorganic phosphorus required.

‡If corn constitutes half of scratch grain mixture, the level of vitamin A in the mash can be reduced by 1000 I.U./lb.

consume more food than smaller ones. Younger animals will consume a larger amount of food per pound of live weight. The more pounds of eggs laid, the larger the amount of food consumed. In fact, the correlation between the number of eggs laid and the amount of food consumed is very close.

Titus[38] indicates that the gross maintenance requirement of White Leghorn hens, 16 months old and weighing on an average 1632 grams (3.6 pounds), was estimated to be 64 grams (2.26 ounces) of the special feed mixture used (containing 17.5 to 18.5 per cent protein, 4.0 to 4.2 per cent ether extract, and 2.4 to 2.5 per cent fiber) per bird per day during July. The amount of this special feed mixture required, over and above the maintenance requirement, to produce an egg was estimated as being about 40 grams (1.41 ounces).

A report from Denmark[39] states that the daily ration for maintenance may be computed for practical purposes at 70 grams (2.5 ounces) of grains for laying hens of the Italian breed, weighing 1.8 kilograms (3.96 pounds); and for hens of the middleweight breeds weighing 2.7 kilograms (5.94 pounds), at 80 grams (2.86 ounces) per bird. A mixed food supplement should be given which should contain 16 per cent of digestive pure protein in order to furnish the quantity of proteins needed by the hens. For the production of 1 kilogram (2.2 pounds) of egg, 1.1 kilograms (2.42 pounds) of mixed food was necessary, containing 95 Scandinavian food units or 67 kilograms (147.4 pounds) of nutritive value in 100 kilograms (220 pounds).

From the results of various scientific and practical experiments, Axelsson[40] has calculated the general food requirement of fowls for different live weights and different intensities of production (Table 27).

TABLE 27. FOOD REQUIREMENT OF THE LAYING FOWL (POUNDS PER DAY PER 100 BIRDS)

Average Live Weight, lb.	Maintenance	Egg Production (Approx Percentage)									
		30	35	40	44	48	52	57	61	66	70
3.85	17.5	21.7	22.1	22.8	23.3	24.0	24.5	25.2	25.6	26.3	26.8
4.40	18.6	22.8	23.3	24.0	24.5	25.2	25.6	26.3	26.8	27.5	28.0
4.95	19.8	24.0	24.5	25.2	25.6	26.3	26.8	27.5	28.0	28.7	29.1
5.50	20.7	24.9	25.4	26.1	26.6	27.3	27.7	28.4	28.9	29.6	30.1
6.05	21.7	25.9	26.3	27.1	27.5	28.2	28.7	29.4	29.8	30.5	31.0
6.60	22.6	26.8	27.3	28.0	28.4	29.1	29.6	30.3	30.8	31.5	31.9
7.15	23.3	27.5	28.0	28.7	29.1	29.8	30.3	31.0	31.5	32.2	32.6
7.70	24.0	28.2	28.7	29.1	29.8	30.5	31.0	31.7	32.2	32.9	33.3

These figures are intended to apply to birds in their first laying year. They apply to average conditions which prevail in spring and autumn. For winter conditions, they may need to be raised about 10 per cent. In very hot weather a reduction of 15 to 20 per cent may be desirable. For older birds, they may be reduced by about 5 to 15 per cent of the maintenance requirement.

Byerly[19] suggests the amounts of daily feed for 100 layers with different rates of production given in the accompanying table.

	WEIGHT OF BIRD				
Per Cent Production	3 lb.	4 lb	5 lb.	6 lb.	7 lb
0	12 8	15.5	17 9	20 2	22.3
10	14.2	16.9	19 3	21 6	23 7
20	15.6	18 3	20 7	23 0	25 1
30	17.1	19.8	22 2	24 5	26 6
40	18.5	21 2	23 6	25 9	28 0
50	19.9	22 6	25 0	27 3	29 4
60	21.3	24 0	26 4	28 7	30 8
70	22.7	25 4	27 8	30 1	32.2
80	24.2	26 9	29 3	31.6	33 7
90	25.6	28 3	30 7	33 0	35.1
100	27.0	29 7	32 1	34 4	36 5

Records at Cornell University indicate that a flock of Leghorns, averaging 4 pounds in weight and not producing, consumed 1⅓ pounds of feed per hen per week. This represents about 19 pounds per day for 100 hens. The same flock, producing 50 per cent, consumed 1⅔ pounds per hen per week, or about 23 pounds per day for 100 hens. Larger hens will require more feed, smaller ones less Also more feed will be necessary for higher levels of production The accompanying figures are given as suggested quantities of feed necessary for average Leghorns (weighing 4 pounds):

Per Cent Production	Pounds of Grain and Mash per Day for 100 Birds
20	21
30	22
40	23
50	24
60	25
70	26
80	27

For heavier birds, such as the American breeds, the amount should be increased 2 to 3 pounds, or approximately 2 pounds for each pound increase in body weight.

The following formulas have also been suggested for calculating the amount of food required:

(1) Total daily feed for 100 birds = 8.3 + 2.2 times the weight of the bird + 0.1 times the egg production.

(2) Feed per hen per year = 31.5 + 8 times the weight + 0.1 times the egg production.

The problem in feeding is to get the birds to consume enough feed daily. Food consumption must stay above a minimum level, which is not always easy to do. For various reasons, some of them often difficult to determine, the birds may refuse to eat what they should. At the same time they usually become inactive.

It has been the experience of many persons that food consumption can be maintained or increased by liberal grain feeding. Jones of Connecticut[41] states that the amount of grain fed 100 birds a day should not be less than 12 pounds during the fall and winter. The New Jersey Station[42] indicates that a study of egg-laying contest records shows that during November to February egg production is proportional to the amount of scratch grain consumed, up to 15 pounds daily per 100 birds; that there is no relationship during March to October; that egg production increases with the amount of mash consumed during the winter and summer-fall periods.

Decreased food consumption may be due to a decrease in the mash or the grain or both. When food consumption decreases, steps must be taken immediately to increase it. There are various means of accomplishing this, and in most cases the means need be only temporary until the birds respond.

One of the first measures resorted to for increased food consumption is the feeding of a wet mash. It usually increases mash consumption because the wet mash is more palatable and can be easily eaten. It is only a temporary measure since the birds will, after a time, adjust their intake with the dry mash.

Artificial illumination may be a means to increase food if the length of day is limited.

Another practice to increase food is to give the birds liquid milk to drink. They like it, and it acts as both food and drink.

The feeding of palatable foods, such as condensed milk, green-cut bone, fresh meat, and blood, may be justified at such times as appetizers.

Changing the grain might increase food consumption if the grain which they prefer at the time is fed.

Frequency of feeding grain or giving fresh supplies of mash may stimulate activity and increase food consumption. The feeding of pellets, as a supplementary food, has also been reported favorably in this respect.

In order to obtain sufficient food intake it is necessary to provide enough feeding space.[43] Forty-eight feet of feeding space for 100 birds is satisfactory. It has also been shown that watering equipment is important since a flock laying at a high rate of egg production will consume considerably more water than the same flock laying at a low level.

For further information concerning the amount of feed see Chap. 19, "Economics of Feeding."

METHODS OF FEEDING

Besides supplying the correct kinds and balance of nutrients, it is also necessary to make the birds consume sufficient amounts of the nutrients in order to supply the materials for the eggs as well as to maintain the body weight. To do this often involves methods and management.

It is generally agreed that it is desirable to keep the birds busy to stimulate activity. If the hens are on range and outdoors, they will get exercise; but if they are closely confined, they might be too inactive. Feeding grain in litter will help to induce activity.

A general working rule is to keep the birds a bit hungry in the early part of the day, but gradually to fill them up so that, by night, they go to roost with full crops. This usually means limiting the amount of grain fed in the morning, in order to increase mash consumption during the day, and then feeding all the grain the birds can eat at night.

METHODS OF FEEDING GRAIN. The grain may be fed by hand in a litter or it may be fed in troughs. The birds will usually eat the grain when given a choice. If the amount of grain is restricted, the fowls can be induced to consume more mash. Birds should be fed according to their condition and production. No definite rule can be given to apply to all conditions of season and production

Grain fed in the litter should be fed scantily in the morning: about 1½ to 2 quarts to 100 hens. No grain should be left in the litter at noon, for that would indicate that too much grain had been fed in the morning. The hens should be given all the grain that they will eat in the late afternoon so that they will find it

before dark and go to roost with a full crop. Usually enough is fed so that a small amount is left over for the morning. All the grain should be fed in a dry, clean, straw litter, 4 to 6 inches deep.

When grain is fed in troughs, the birds should have it available early enough in the afternoon so they can eat what they want before going to roost. About 4 P.M. is the usual time for opening the grain hoppers except during the winter months, when no artificial illumination is used at night. Then the time must be advanced. In trough feeding of grain, little or no grain is fed in the morning. Frequently a light morning feed of grain is given in the litter. Trough feeding of grain is practiced with deep-litter management.

Continuous hopper feeding of grain may be practiced. With grain available all the time, the birds usually eat large amounts of it. Thus it may be necessary to restrict the grain at times in order to regulate the proportion of grain to mash, or to use a mash that is more concentrated. If the heavier grain consumption is maintained, extra vitamin and protein carriers must be added to the ration.

Sometimes the grain is fed only at night, particularly during the more favorable seasons of the year and when the birds are on range. But sometimes grain is fed more often, as, for example, when the birds are fed grain twice during the morning in very small quantities. This is often the practice during the winter when the birds are inclined to be inactive. By feeding them a little at a time and frequently, it is sometimes possible to keep them more active than if they were fed once in the morning or fed heavily. This is particularly true of the heavier breeds, which have a tendency to be sluggish.

The amount of grain to feed depends upon the appetites of the birds. No definite rule can be given to apply to all conditions. When grain is fed both morning and night, about three-fourths of it should be given at night and the rest in the morning and at noon. The tabulated amounts are suggested as the approximate grain feedings each day for 100 laying hens, averaging 4 pounds in weight.

Month	Morning Feeding	Night Feeding	Total Grain
November—February	3	10	13
March—June	2	10	12
July	. .	11	11
August	. .	10	10
September—October	. .	9	9

The common straws for litter in the order of their desirability are wheat, oats, rye, and buckwheat. Shredded or cut corn stalks, shavings, peat moss, oat hulls, or leaves may be used if straw is not available, especially where trough feeding is practiced. The litter should be clean and free from mustiness, mold, or decay, as serious losses frequently occur when spores develop into fungus molds in the lungs or intestines of the fowls.

METHODS OF FEEDING MASH. Under most conditions it is advisable to feed the mash dry in hoppers, troughs, or boxes, having it available at all times. The open hoppers are desirable since they permit the hens to have frequent fresh supplies of mash. Open boxes, if used, should be raised from the floor. To prevent waste where a reel or wires are not used, a piece of 1-inch mesh poultry netting should be placed on top of the mash. Sufficient hopper space should be provided. A trough 20 feet long, feeding on both sides, should be furnished for 100 hens. With mechanical feeders all-mash rations are used.

Moist mashes, when fed, are usually given sometime the latter part of the day. The plan is to induce the birds to eat as much of the dry mash during the day as they will, and then to consume an additional amount in the form of the wet mash, so as to fill them up by the time they get their feeding of grain.

FEEDING GREEN FEEDS. Where fresh green foods are provided, only as much should be given as the fowls will eat the same day or before it freezes. It is best to feed it during the middle of the day. It is not advisable to feed too much succulent feeds since they might decrease grain and mash consumption. About 4 to 6 pounds a day for 100 hens is sufficient.

PROPORTIONS OF GRAIN AND MASH. It is important to follow the directions for the particular ration that is being used. Practice the recommended methods that accompany the mixtures you decide to use because the methods of feeding are devised to meet the make-up of the mixtures themselves, particularly in regard to the proportion of grain and mash to feed. The proportions of grain and mash that are recommended have a close relationship usually to the amounts of protein, minerals, and vitamins which the mash contains.

ARTIFICIAL ILLUMINATION

Although the direct effect of light is stimulation of the reproductive system, artificial illumination in the northern latitudes is also largely a nutritional consideration.[44] The birds must be

given sufficient time to assimilate enough feed to produce the eggs. The naturally short days or, more important still, the naturally long nights during the fall and winter are great handicaps to the hen. First, the hen must have a sufficiently long day in which to feed and exercise. Next, the night must not be too long or the assimilated food will be drawn upon to maintain the body rather than to make eggs. Experience has shown that ordinarily the hens should not go without food for more than about 10 hours, that is, they should have a 13- to 14-hour day. In this connection, it is well to keep in mind that on September 21 and March 21 night and day are of equal length. After September 21 the nights are longer than the days. For early-laying pullets and late-laying hens, the lights should be used not later than the first of September. For the later pullets, they should be put on when the chickens are placed in winter quarters.

When artificial illumination is used in the poultry house, the grain and mash mixtures remain unchanged, but the method of feeding must be adapted to the method of illumination. Though the underlying principles are the same, the time of feeding must be arranged to fit the working hours of the birds. In order that activity may be encouraged, grain should be fed lightly at the beginning of the hen's day. If morning illumination is used, the grain may be scattered in the litter the night before. The dry mash and water should be available during the entire time that the birds are off the roost. Grain should be fed heavily at the end of the day (with either natural or artificial lighting), about one hour before the birds go to roost. Green food should be supplied in the middle of the birds' working day.

Watch the condition of the birds, since they might have a tendency to produce eggs at the expense of their bodies. Hence it is necessary to observe the birds closely, with special attention to their weight, which is one of the best measures of condition. If they begin to lose flesh, increase the amount of grain fed and supplement it with a wet mash.

MODIFICATIONS DURING THE YEAR

For the best results, it is advisable to segregate the birds according to their condition and to manage them accordingly. Better results will be obtained if the birds in the flock are nearly alike in their conditions and consequently in their requirements. Different feeds must not always be used for each group; more often the variation will come in the manner of

feeding the same ration and in the management of the flock.

FEEDING PULLETS. It is particularly important that pullets have fat in the body when they commence to lay and that they be kept in good flesh. The pullets that are thin when they begin to lay are most likely to molt. If the birds are not being handled regularly, as in trapnesting, it is a good practice to band a few of them and weigh them regularly. Good food consumption is required to meet the needs of growth as well as egg production. To encourage liberal grain consumption, keep the grain in hoppers before the pullets all the time for the first month or 6 weeks of production. After that time the grain may be fed only in the morning and in the afternoon. Always let the birds eat all the grain they want at night. The urge to lay will cause pullets to produce for a considerable period of time even on a deficient ration but at the expense of their bodies. It is well to house pullets when they start to lay and thus give them proper attention before they have lost flesh laying on range. The pullets should not only maintain their weight and flesh but should actually be completing their growth during the first few months of production. To produce eggs at the expense of their body weight, or as we say "to lay themselves out," is positively detrimental.

It is better to encourage production in early hatched pullets than to retard them when they are ready to lay. Pullets at Cornell[45] fed an egg mash gave better results than pullets retarded. The forced pullets made better profit, ate less food per hen at less cost, produced more eggs of a larger size, produced more eggs during the winter, had better hatching results, made better gains in weight, showed less broodiness, had less mortality, and showed better vigor.

Pullets that, because of early hatching or rapid development, have come into production early (August or September) will show a tendency toward decreased production, owing to the shortening days late in September and October, and to cold weather. At this time a decided slump in production, followed by a molt and a period of unproductivity, often occurs. This class of birds needs careful observation. It is of prime importance to maintain the weights of the individuals. Whenever the birds are losing weight or production begins to decrease, consumption of one part of the ration or of the feed as a whole usually decreases also. Introduction of milk, pellets, wet mashes, or artificial illumination of the poultry house at the proper time will help to overcome this difficulty. The lights should usually be turned on by September 1.

For later-hatched pullets, lights need not be used until October. It is well to hopper-feed grain to these pullets all the time also for a month or more after they are placed in winter quarters.

WINTER MANAGEMENT. The winter management of layers presents problems not met with in spring and summer production. Closer confinement and unfavorable climatic conditions make it more difficult to maintain high production and the health of the individual. To prevent a slump it is again necessary to maintain the weight of the birds by proper food consumption. It is better to decrease production somewhat for a time, to build up the birds, rather than to cause a break in production. Very high production usually cannot be maintained throughout the winter without a slump or molt, unless conditions are favorable.

During the spring and summer, when the conditions are favorable, it is possible to obtain 75 to 80 per cent production without harm to the birds. With such heavy production, however, one must be sure that the birds are being favored in all respects. It means a complete ration and heavy food consumption.

CARE OF BROODY HENS. Broodiness is a natural characteristic of the birds, the natural tendency to incubate the eggs and rear the chicks. When a hen becomes broody, the ovules that are not of mature size are reabsorbed into the body. It takes about 2 to 3 weeks to develop these minute ovules to mature size. They are reabsorbed, however, in a shorter period of time. If we can take a hen right at the time she begins to get broody and stimulate production, we shall check the reabsorption of the ovules and stimulate their formation. We can make her continue to produce and show a break for only a very short period. If we get a hen right away, production will be resumed in the course of 2 or 3 days. If we allow the hen to remain broody, reabsorption of the ovules takes place and the time that it will take for that hen to come back into production again depends largely upon the time at which we arrest the reabsorption of those ovules.

In handling our flocks for egg production we are interested in breaking up broodiness and getting the hens back into production. How can we overcome this broodiness? How can we stimulate that production? First, we need to discourage inactivity of the broody hen. When the hen becomes broody, she usually stays on the nest and in so doing she starves herself, because she does not get off the nest long enough to eat what she needs for egg production. The first thing to do is to remove the bird from the nest and place her in quarters that will prevent this absolute inactivity. Put her in a broody coop, which usually has a wire or

slatted bottom to discourage setting and inactivity. Then feed some stimulating feeds, feeds that will encourage production. It has been found best to give the broody hens a moist mash. Do not feed grain. Give them water or milk to drink.

Broodiness can often be induced by restricting the feed. Where the hens are not given full rations or where they are starved, we get considerably more broodiness than where they are given plentiful feed.

If we want the hen to set, we feed only for maintenance. Therefore, the ration is usually restricted to grains. The hens can be given access to the grain and grit in hoppers. Water must also be given.

LATE SUMMER AND FALL MANAGEMENT. Production during late summer and fall is accomplished under conditions that normally are not favorable. In order to hold production, the mash consumption must be increased. However, Heywang[46] concluded that it is not advantageous to reduce the proportionate amount of grain in a mash-grain diet for laying chickens during hot weather in order to increase the protein level This usually calls for wet mashes or other supplementation during the late summer and fall. Artificial illumination of the poultry house also gives the birds a better chance. The lights should usually be turned on not later than August 15 for hens at the end of their laying year.

CARE DURING THE MOLT. The molting of a hen is a natural characteristic, but the time of the molt and the nature and length of the molt can be influenced to quite an extent by feeding and management. Molt can be brought on by restriction of the feed and by starvation. The question often arises whether it is not advisable to force the hens into a molt late in the summer with the idea that they will come back into production again during the winter and lay high-priced, winter eggs This sounds as if it might be possible, but it has been found that, even though the hens might lay a few more winter eggs, when the production and the returns throughout the year are considered, it is not a paying proposition because some fall eggs, which are also comparatively high-priced, will be sacrificed.[47] Furthermore, to force the hens into a molt, it is necessary to restrict the feed, and by restricting the feed we are likely to get a loss in body weight It is very difficult to force the molt of some hens successfully, except during the normal molting season. It is best to let the molt take its normal course or, if anything, to prevent the molt until late in the fall.

It is possible, however, on the other hand, to keep the birds in production for too late a period. For the central New York region, probably somewhere around the first to the middle of November is late enough for any hens to keep in production. The time to stop will depend upon our ability to get the birds far enough along with their molt so that they may have the protection of the feathers by the time cold weather sets in. If the birds are kept in production too late and shed their feathers rapidly (this is likely to happen since it is the best birds that can be kept in production and thus the best birds will drop most of their feathers at a time), they are likely to be affected by the cold weather because of not having the protection of the feathers. This will delay recovery from the molt and postpone production.

When the hen stops production in the fall and goes through the molt, she needs the various nutrients just as when she was in laying condition. She probably does not need as much of the protein, although she needs considerable to grow new feathers. She will need fattening material to make up or to replace the decreased amount of body fat which we find hens lacking at the end of the laying season, especially when they have been held in fairly high production in the late fall. Since they are likely to be thin, body fat used up, and pigment gone, we need to get all this replaced to bring the bird back into good, plump, healthy condition, and with an excess or store of fat which can be drawn upon in the next production year. That means that when the hens stop production they may be fed more heavily on the grain but that they also need mash.

Hens that have stopped laying during August and early September can be brought back into production, so as to be put under lights by October 15 to November 1, by placing them on a clover or alfalfa range and hopper-feeding grain and mash. They will then respond well for winter production.

FEEDING THE BREEDS

Are the requirements for the heavier breeds different from those of the lighter breeds? Naturally, total food requirements are greater for the larger birds. The feed records at laying contests indicate that the heavier breeds consume more of the mash in proportion to the grain than the lighter breeds. Sometimes better results seem to be obtained when heavier breeds are given a slightly narrower ration. The variation is usually not in the feeds themselves so much as in the method or system

of feeding. The grain feeding of the heavier breeds is restricted in order to get the birds to consume larger amounts of the mash. The restriction of the grain also tends to keep the heavier birds more active. Their natural sluggishness is overcome to some extent in this way. For that reason it seems desirable not to change the mixture, not to put more protein in the mash and then feed heavier on grain, but to keep the same mixtures and vary the method of feeding by restricting grain, thereby reducing activity and getting the birds to eat more of the mash. Because of less activity, they probably do not need quite so much of the grain as the lighter breeds.

The results of experiments in Denmark[39] indicate different levels of protein for birds of light and medium heavy breeds. The light birds, Brown Italian, required 10.5 to 11 per cent of digestible true protein, provided by a daily ration of 65 grams of grain, with free access to a mixture containing 16 per cent of digestible true protein. The heavier breeds, Plymouth Rock, Rhode Island Red, and Sussex, required slightly more total protein and so ate more of the free access food. No advantage was gained by feeding more protein than was provided in this way, but egg yield fell in proportion as the supply fell short of this level.

It has been shown, in the case of young stock, that the requirements of different breeds may differ for some of the vitamins and minerals. It is also possible that the same may be shown to be true for the requirements of adult birds, in respect to some of the nutrients.

SLUMPS IN PRODUCTION

When birds that have been laying heavily suddenly slow down, a neck or a complete body molt is likely to accompany this slump, after which it may be weeks before the flock can be brought back into good laying again, depending upon the condition of the birds and the extent of the molt.

The actions of the birds frequently foretell slumps. General activity and singing and cackling denote that all is well. Squawking, lack of interest, huddling in the corner, and dopiness denote trouble ahead.

Slumps may be brought on by various things.

1. POOR STOCK. The birds do not have the ability to stand up under the strain of heavy production

2. POOR ENVIRONMENT. Heavy, damp, or dirty litter and

improper ventilation will affect the condition of the birds.

3. EXTREME TEMPERATURE. Extreme cold or hot weather and sudden changes will affect the birds adversely. In cold snaps, be sure the birds eat enough. Warm the water and also the other feed if necessary. Extremely hot weather requires increased shade. Provide cool water several times a day and furnish succulent green feed.

4. POOR CONDITION OF BIRDS. (a) Loss in weight. This is usually caused by decreased food consumption. (b) Diseases, such as chicken pox and colds, will cause decided slumps.

5. TOO SHORT DAY. Food consumption can be increased by using artificial illumination. Effects can be secured usually by increasing the length of day up to 15 hours.

6. DEFICIENT RATION. Any deficiency will cause a drop in production.

7. WRONG FEEDING. (a) Lack of appetite. This is often caused by feeding too much grain in the morning. Increase palatable feeds. (b) Indigestion might affect the lay. (c) Spoiled or poor-quality feed.

CONFINEMENT

In early experiments,[48] reported by the Ohio and Pennsylvania stations, confinement of hens did not produce as good results as giving them range. However, these results were obtained before our knowledge of vitamins. Range supplements the ration with sunlight, green feed, fresh air, and contentment.

With the development of commercial poultry keeping, layers are being confined to a greater extent. It frequently has been necessary because of contaminated soil. Where weather conditions are unfavorable, the birds are benefited by being confined. Sometimes there is also decreased mash consumption, owing to the birds staying outdoors.

The key to success in keeping hens in confinement is a complete ration. Confinement also requires more exact feeding and management in order to avoid such vices as cannibalism and feather pulling. However, with proper rations and management, just as good production can be obtained from birds confined as from birds allowed to range. For example, the Ohio Station[49] reports 122 eggs from hens having a bluegrass range, as compared with 127 from hens confined but having a sun porch, and 132 from hens confined indoors but with the windows open. Reporting on the cage system for managing laying hens, the New

Mexico Station[50] shows that the average annual egg production was materially higher with White Leghorns, Rhode Island Reds, and crosses in cages, than it was with birds in floor pens. The mortality rate was also lower with the birds in cages. The feed costs were slightly higher in the cages because of higher production and a more expensive diet for cage birds.

CARE OF LAYERS IN CAGES

Because the birds are in strict confinement with restricted activity, it is necessary that conditions and management be correct in order to get the best results. Some of these provisions are adequate housing for the cages, with proper ventilation of the battery room, suitable supply of birds, and proper feeding.

The ration must be complete. Either all-mash or grain and mash rations can be used, but the former is preferred because of the difficulty of feeding grain in right amounts to each individual. Pellets have also been fed satisfactorily. A single-feed mixture is more convenient and requires less skill in use.

Fresh feed is given at least once a day and preferably twice a day. There may be times when the food intake needs to be increased. This can be accomplished by feeding supplementary wet mash or pellets.

Some rations for cage layers include oystershells and grit. If not, they can be provided separately. They can be fed either on top of the feed or in separate troughs. Enough should be supplied so that there is always a little present in the troughs.

EMERGENCY SUBSTITUTIONS FOR MASH

Sometimes an emergency might arise when the regular mash is not available. The question then arises as to what will happen to egg production and what can be done. Platt[51] reported that an absence of mash for 6 days, if grain was available on the cafeteria basis, would have no serious effect upon egg production. If, however, it was extended to a period of 12 days, a significant curtailment would be realized, and this drop in egg production could be alleviated to some extent by feeding cooked whole soybeans plus a mineral mixture, or by diluting the normal mash with an equal quantity of yellow corn meal plus a mineral mixture.

At Cornell the laying mash was taken away from a pen of layers for 10 days during January. Grain consumption increased

ut not enough to keep up total feed intake. There was a drop rom approximately 55 per cent production to 35 per cent the reek following, after which time the birds increased in production again, coming back to a normal level in about 2 weeks. In nother trial the laying mash was replaced for 2 weeks during pril by a mixture of 40 per cent corn meal, 20 per cent wheat niddlings, 20 per cent wheat bran, and 20 per cent ground oats. Total feed consumption again decreased somewhat and there vas a drop in production of about 15 per cent the week after the nash without animal protein was fed. The birds had again eached normal production in about 2 weeks after the regular aying mash was restored.

It is important to keep up feed consumption. It can be accomplished better by feeding both whole grains and ground feed. Any means can be used, such as wet mash feeding, which have been found successful for maintaining or increasing feed intake.

COMPUTING RATIONS FOR EGG PRODUCTION

The final measure of a ration is the result it actually will produce. However, it is frequently necessary, as well as interesting, to compute the various nutrients in a ration and make adjustments in their relationships.

For example, we may want to know the nutrient content and protein energy-ratio of a ration. The following mixtures may be used as a problem:

Grain, lb.	Dry mash, lb.
100 cracked corn	100 corn meal
100 wheat	100 wheat bran
	100 flour wheat middlings
(To be fed equal parts	100 ground heavy oats
by weight of grain	75 meat scrap
and mash.)	25 dried milk

In Table 3 (page 56) we see that 100 pounds of corn contain 2.0 pounds of fiber, 8.6 pounds of protein, 3.9 pounds of fat, and 69.3 pounds of nitrogen-free extract. The same table shows the amounts of fiber, protein, fat, and nitrogen-free extract in the other feeds. From this information, it is calculated that the mixtures will contain the amounts of these nutrients given in the accompanying tabulation.

As suggested in the method of feeding this ration, the hens

GRAIN MIXTURE

	Fiber	Protein	Fat	Nitrogen-Free Extract
100 lb. corn	2 0	8.6	3.9	69.3
100 lb. wheat	3.0	13.2	1.9	69.9
200 lb. grain mixture	5.0	21.8	5.8	139.2
100 lb. grain mixture	2.5	10.9	2.9	69.6

MASH MIXTURE

	Fiber	Protein	Fat	Nitrogen-Free Extract
100 lb. corn meal	2 0	8.6	3.9	69.3
100 lb. wheat bran	9.6	16.9	4.6	52 9
100 lb. flour wheat middlings	3.8	18 3	4 2	59 8
100 lb. ground oats	11.0	12 0	4 6	58.6
75 lb. meat scraps	0.9	41.9	8 2	0 4
25 lb. dried milk	...	8 7	0 3	12 6
500 lb. mash mixture	27.3	106 4	25 8	253 6
100 lb. mash mixture	5.5	21.3	5 2	50 7

should eat about equal parts of grain and mash. The nutrients of this ration, therefore, may be calculated as follows:

	Fiber	Protein	Fat	Nitrogen-Free Extract
100 lb grain	2 5	10 9	2 9	69 6
100 lb. mash	5 5	21 3	5 2	50 7
200 lb. ration	8 0	32 2	8 1	120 3
100 lb ration	4 0	16 1	4 2	60 2

This ration, then, has 4.0 pounds of fiber, 16.1 pounds of protein, 4.2 pounds of fat, and 60.2 pounds of nitrogen-free extract for every 100 pounds of feed.

It remains to compute the protein-energy ratio.

RULE FOR COMPUTING PROTEIN-ENERGY RATIO. Add the fat (4.0) multiplied by 2¼ (9.8) to the nitrogen-free extract (60.2), which gives the total energy nutrients (69.2). Total energy nutrients (69.2) divided by protein (16.1) equals protein-energy ratio (4.3). Therefore, the protein-energy ratio of this ration is 1–4.3, which means that for each pound of protein the ration contains 4.3 pounds of carbohydrates and fat.

BALANCING RATIONS. In balancing a ration, amounts of available feeds should be used as seem desirable. Then the nutrients should be calculated as above. If it is found that the protein-energy ratio is too wide (containing too large an amount of carbohydrates and fat to one part of protein), the amount of one or more feeds that contain a large proportion of carbohydrates and fat should be reduced and one or more feeds that contain a larger proportion of protein should be substituted. If it is found that the protein-energy ratio is too narrow (containing too small an amount of carbohydrates and fat to one of protein), the amount of one or more feeds that contain a large proportion of protein should be reduced and one or more feeds that contain a larger proportion of carbohydrates and fat should be substituted. After a few such trials, it should be possible to formulate a ration that will meet the requirements. One must not forget that the mixtures must be considered also from the standpoint of palatability, mechanical condition, and other factors previously discussed.

If the digestible nutrients and the nutritive ratio are desired, the same procedure is followed as above, except that the values for digestible nutrients are used instead of the crude nutrients.

RATIONS FOR EGG PRODUCTION

It is possible to formulate a large number of rations that will meet the requirements. The ingredients used will depend largely upon the availability of the feedstuffs. Some of the representative rations being recommended for layers will be found in the Appendix. (See page 554.)

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CHAPTER 14

FEEDING AND MANAGEMENT OF BREEDERS

There is a relationship between feeding and management of the poultry flock and hatching results. We are dealing with a reproductive process that is more exacting and apparently is influenced by more factors than only the production of eggs. It is entirely possible to secure large numbers of eggs and still not obtain eggs that will produce satisfactory hatching returns. For example, the hens in two pens at Cornell University, receiving different rations, gave satisfactory and uniform production (averaging in each case 211 eggs per bird for the year), but the hens in one pen hatched only 27.5 per cent of the fertile eggs set in February, whereas the other hens hatched 71.4 per cent. Besides numbers of eggs, especially during the hatching season, we must get eggs that not only are fertile but also are capable of producing chicks of good quality, healthy, and vigorous.

Hatchability or the ability of eggs to produce chicks is influenced by many factors,[1] some of them beyond the control of the average poultryman. For instance, some hens consistently produce eggs that are infertile or, if fertile, will not hatch.

But, in order to produce good fertile eggs that will develop vigorous chicks, it is necessary to care properly for the breeders. It is necessary to put the quality into the egg because during incubation the embryo develops within the egg independent of the hen. Thus there is inside the egg a developing individual which must be furnished suitable growth conditions.

NUTRITIONAL REQUIREMENTS FOR HATCHABILITY

Proper food or building material is a first essential which we cannot supply except through the hen. If all the necessary food nutrients are not in the egg, growth will be handicapped until the time when additional food can be furnished, which is not until after the chicks are hatched. This early, embryonic life is much more important than any other equal period and gives the chicks a start which will not easily be overcome.

In order to produce this quality in the egg, the breeding flock must be given proper attention, not only during the hatching season, but also for some time previous to it.

The nutrition of the hen is one of the most important considerations affecting hatching results. Anything that affects the condition of the birds will affect hatchability. For example, it has been reported that hatches were decreased where the hens were fed scantily. In that case, the hens probably depleted their bodies by drawing upon body reserves. Any practice that will keep up a balance of nutrients in the bird will increase or maintain hatchability. Any deficiency, be it vitamin, mineral, or protein, will decrease hatchability by affecting the health and condition of the bird.

PROTEIN. Not only is a proper amount of protein necessary,[1] but the feeds must also furnish enough of the right amino acids. An excess of protein to be eliminated will place an extra strain on the animal; a deficiency will prevent it from functioning properly.

It has been shown that rations low[2] in protein give low hatchability. This may be due in part to the fact that these rations frequently contain little or no protein concentrates. The United States Department of Agriculture[3] reports that in birds receiving a low-protein diet the trend in hatchability tended to parallel the trends in egg production and egg weight during the first year of production.

The Oklahoma Station[4] reported that, although the embryos from the high-protein hens were heavier during the greater part of the incubation period as shown by both wet weight and dry weight, the differences were shown by an analysis of variance to be insignificant. A further report indicates that in two experiments out of three the chicks produced by the hens on the high-protein levels were smaller than would be expected, whereas the chicks produced by the hens on the low levels were larger than would be expected. In hens the differences were significant, whereas in pullets they were not significant.

Some reports show no difference in hatchability between vegetable and animal protein concentrates.[5] In general, however, the use of vegetable protein concentrates has resulted in decreased hatchability. This is particularly true of cottonseed meal.[6,7]

The South Carolina Station has further shown that the addition of crude cottonseed oil to a satisfactory ration for hens markedly reduced the hatchability of the eggs, as did also refined oil produced by filtering and alkali treatment. Gossypol[8] has been

shown to be a factor having an adverse effect on hatchability.

The Alabama Station[8] also reports lower hatchability from a ration containing soybean meal but comparable results with the one containing peanut meal. A number of other workers[9] have reported that soybean oil meal, as the sole protein supplement in poultry rations, fails to support good hatchability. It has been demonstrated that such rations may be deficient in manganese and riboflavin. It has also been suggested that there may be a relationship between the goitrogenicity of soybean oil meal and the poor reproduction.

The United States Department of Agriculture[10] reported that diets containing proteins from vegetable sources only increased the incidence of chondrodystrophy in embryos of hens likely to produce such embryos. Embryos in eggs from hens on such diets has a high second-week mortality.

Parkhurst[11] reported greater hatches from rations containing animal protein than from one containing no animal protein, both alone and in combination with various feeds of high vitamin content.

In comparing rations containing meat scraps with those containing milk as the source of animal protein, most experimenters report better hatchability with the milk ration.[12-18] The difference in favor of the milk has usually been about 10 to 15 per cent.

The South Carolina Station[19] indicates reduced hatchability with fish meal. Reports from Canada[20] show no influence on hatchability or viability of chicks by the addition of bone meal to the ration. Results from the Ontario Agricultural College[21] indicate that there is a difference in the protein sources as to the hatching power of the eggs produced. The best hatches came from milk and fish meal. In general, during an 11-year study with Barred Plymouth Rock pullets, the use of dried buttermilk as the protein supplement has resulted in higher hatchability than either fish meal or meat meal. During the last 6 years of this period the buttermilk showed decided superiority. The decline in meat meal may be due to the lessened amount of liver and other glandular material. It seems probable that there may be a decided variation in the value of different meat or fish meals for hatching rations, depending on the materials used in their manufacture and processing procedure.

The improved hatchability of rations containing animal proteins may be due in part to their vitamin values. This is true especially of milk, in which, no doubt, riboflavin plays an important part.

The amount of protein is the same as for layers. (See page 383.) No difference has been shown in the amino acid requirements for hatchability as compared with those for egg production only. (See page 384.)

MINERALS. Possibly some of the difference between animal and vegetable proteins may be due to the more favorable mineral content of the animal protein concentrates. The Kentucky Station[22] has shown that calcium restriction decreased hatchability. In the absence of a calcium carbonate supplement, the hatchability of fertilized eggs was diminished, finally becoming zero. When oystershells were again supplied, hatchability was increased. The Kentucky workers also found that, in the absence of a calcium carbonate supplement, the percentage of infertile eggs was increased, the chicks hatched weighed less, and the ratio of the weight of the moisture-free carcass of the chick to the original weight of the contents of the egg from which it was hatched was less.

Results reported from the National Agricultural Research Center[23] show that, in general, a high level of calcium intake adversely affected the hatchability of the eggs, and the effect was more pronounced in the hen's eggs than it was in the pullet's eggs. The hatchability of the eggs was better when calcium carbonate was used as the source of calcium than when calcium sulphate (gypsum) was used.

The level of phosphorus intake was reported[23] as having no effect on hatchability. However, the highest levels of calcium intake affected the hatchability more adversely when the level of phosphorus intake was 0.9 per cent than when it was 1.2 per cent. With a deficiency of phosphorus embryo mortality occurs mostly in the first 2 weeks. A level of 0.3 per cent of phosphorus has been shown to be sufficient.[24]

Manganese[25, 26] has also been shown necessary for good hatchability. The Kentucky Station reported a hatchability of less than 10 per cent from hens fed a low manganese ration (13 parts per million). The embryos died during the final stage of incubation and showed short legs and wings and "parrot beaks." The requirement for hens appears to be 40 to 50 parts per million of the ration.

Iodine is necessary for reproduction. Only a few investigators[27] have shown increased hatchability when feeding supplementary iodine. Most of the reports show no benefits, which indicates sufficient amounts of this mineral in ordinary rations.

Toxic grain, because of its selenium content, was reported by

the South Dakota Station[28] to affect hatchability very seriously. Approximately 75 per cent of the eggs that failed to hatch contained deformed embryos.

VITAMINS. In the light of our present knowledge of nutrition, the vitamins undoubtedly constitute the most important nutritional factor affecting hatching results. Improved hatches in the spring and summer can be largely accounted for by access to green food and sunshine.

Vitamin A. It is probable that a deficiency of any vitamin that is necessary will influence hatching. Decreased hatchability reported by Kansas[29] and Oklahoma[30] in lots where white corn was fed was probably due to a vitamin A deficiency. When yellow corn or alfalfa, which are vitamin A carriers, was fed, the hatchability was improved. Fertility was good. Chicks hatched from eggs of birds fed white corn did not have a thrifty appearance. The Oklahoma Station[30] also indicates decreased hatchability from wheat. This was also likely to be caused by a vitamin A deficiency.

Reports from a number of experiment stations[31, 32] indicate that the vitamin A requirement for breeders, where a high vitamin A content of the egg is desired, is greater than for layers.

Vitamin D. It has long been noticed that hatchability improved rapidly after the birds got outdoors in the spring. The improvement was attributed to the birds getting on the ground, access to green food, increased temperature, and many other reasons. It is now generally believed that improvement was due largely to exposure to sunshine, which furnished the antirachitic factor or vitamin D.

The antirachitic factor may be furnished by means of irradiation, or exposure to the ultraviolet rays of sunshine, or artificially produced ultraviolet rays of special lamps, such as the quartz mercury-vapor or carbon-arc lamp. Wisconsin[33] was

TABLE 28. INFLUENCE OF ULTRAVIOLET LIGHT ON HATCHABILITY

Month	Irradiated*	Non-irradiated	Male Only Irradiated
February	66	35	44
March	64	20	11
April	70	0	6
May	68	0	62† 76

* 10 minutes of ultraviolet light

† Hens also irradiated.

one of the first stations to demonstrate that ultraviolet light greatly improved hatchability (Table 28).

The reports from other stations[34-36] also showed the influence of a ration deficient in vitamin D upon hatchability. The Kentucky Station[37] reported that pullets confined to the house and receiving sunlight only through glass windows produced eggs which progressively decreased in hatchability. Ordinary glass windows exclude most of the beneficial rays of ultraviolet light.

The antirachitic factor, or vitamin D, may be furnished by irradiation with ultraviolet light, by exposure to sunshine, or by feeding cod liver oil.[38] This is clearly shown by the following results as obtained in Kansas:

	Per Cent Hatchability
Sunshine	75.45
Ultraviolet light (Quartz lamp)	71.63
Sunshine plus ultraviolet light	67.43
Sunshine through glass	52.90
Cod liver oil (1/2 cc. per day)	74.27

If the windows of the poultry house are allowed to remain open, the birds receive considerable benefit from the sunshine that can enter. Certain glass substitutes are effective in transmitting the ultraviolet rays, but other materials are not effective. The Wisconsin Station[39] reports the following 5-year average results:

	Hatch (March) per cent
Glass closed	13
Glass closed plus irradiation from quartz mercury lamp	59
Glass open plus irradiation from quartz mercury lamp	65
Glass open	45
Glass substitute closed	45
Quartz glass closed	45
White cloth closed	23
Glass closed plus cod liver oil	49

Sunlight is very effective in furnishing the antirachitic factor and increasing hatchability. It has been pointed out by various workers that hatchability often increases more or less in proportion to the amount of sunlight available. Experiments reported from Canada[21] generally show greater hatchability during the summer months of May, June, and July, when the hours

of sunshine are greater, than during the spring months of February, March, and April. With the grain ration such as used, the addition of direct sunshine or sunshine substitutes was the most important factor in producing good hatching eggs. The birds did not get the necessary amount of sunshine until there was at least 200 hours of sunshine per month.

Cod liver oil will improve hatchability by furnishing vitamin D.[40-42] When sufficient sunshine is available, cod liver oil is not necessary. Viosterol[43] has been reported not to be so effective as cod liver oil. Furthermore, an overdose of viosterol still further decreased hatchability.

Differences in hatchability are probably due to differences in egg quality. The Wisconsin Station[33] found that the developing embryo (21 days old) from eggs produced by irradiated hens contained nearly twice as much lime as the embryo from non-irradiated hens' eggs. From this, Hart and his coworkers conclude that low hatching is probably related to low power of the developing embryo to transfer lime from the shell. In this connection, Hughes and his coworkers[44] report that the antirachitic vitamin in the egg is determined by the amount of irradiation and that eggs with low antirachitic vitamin content do not have as high a hatchability as eggs having a high antirachitic vitamin content.

Experiments at the Kentucky Station[45] indicate that an absence of vitamin D decreased the percentage of eggshell and that hens receiving an adequate supply of vitamin D supplemented by pasture tend to produce chicks which grow more rapidly.

Three different yearly experiments at Cornell indicate the effect of ultraviolet irradiation and cod liver oil upon eggshell strength and hatchability (Table 29).

It is believed by some workers[46] that sunshine supplies something, besides vitamin D, that is necessary for good hatchability. The Wisconsin workers[47] also reported that the hatchability of winter eggs was much improved by adding a small amount of manganese to the mash, when soybean oil meal is the only protein supplement in the ration, but that feeding manganese has little or no beneficial effect on hatchability in spring or summer. Their records seem to indicate that the amount of direct sunlight which the hens receive affects their need for manganese, but they were unable to explain the relation of sunlight to the utilization of manganese.

Vitamin E. Vitamin E is recognized as a specific reproduc-

TABLE 29. EFFECT OF ULTRAVIOLET IRRADIATION AND COD LIVER OIL UPON EGGSHELL BREAKING STRENGTH AND HATCHABILITY

Period, 4 Weeks	Quartz Mercury Vapor Arc,	Sunlight,	Cod Liver Oil,	Control,
	lb.	lb.	lb.	lb.
1	10.14	9.89	9.89	9.56
2	10.24	10.12	9.98	9.24
3	10.17	10.10	10.22	9.29
4	10.19	9.73	10.18	7 82
5	10.59	10.20	10.43	7.44
6	9.80	9.88	9.02	6.70
7	9 53	9.76	9 87	5.70
8	9.17	8.86	9 28	5.71
9	8.26	8.45	8.57	4 71
10	7.49	7 91	7.92	4.05
11	7.74	7 87	8 03	4.43
12	7.72	8 17	8 86	4 21
% hatch of fertile eggs	56.4	55.5	67.0	35.2

tive vitamin. A deficiency of it in the ration produces sterility It is found in the germs of cereals. An ordinary mixed grain poultry ration apparently contains enough of this factor for normal reproduction. Most of the reports have shown that the addition of wheat germ oil to a mixed grain ration does not improve either fertility or hatching power. However, a few experimenters[48] have shown increasing hatchability by feeding wheat germ oil.

The necessity of this vitamin for poultry has been shown by experiments at the Illinois Station.[49] In this work the ration was treated with ferric chloride to destroy the vitamin E. It should be pointed out that, from a practical point, there is little cause for concern because all whole grains and many green feeds are good sources of this vitamin

It has also been shown[50] that the normal diet which produced eggs of moderately high hatchability was found to be potent in vitamin E when tested with female rats. The diets which produced eggs of low hatchability, particularly marked by a high first week embryonic mortality, were found to be low or lacking in vitamin E.

Vitamin K. The Wisconsin Station[51] reports that a minimum requirement for laying hens is 1 per cent of dried cereal grass or 2 per cent of alfalfa meal in order to furnish enough vitamin

K to assure that the chicks produced will have normal blood clotting.

Thiamine. In a study of the influence of the antineuritic vitamin upon the internal organs of Single Comb White Leghorn cockerels, Souba[52] reports distinct failure of the testes to grow, with ultimate atrophy of the organs, on a ration deficient in Vitamin B_1. However, poultry rations prepared from the common grains possess an adequate supply of this vitamin.

Riboflavin is also necessary for the maintenance of health and good hatchability. The benefits of milk, already noted under the discussion of proteins, probably is due in large part to the presence of this vitamin. Also the benefits of green food and alfalfa feeding may be attributed in large part to this vitamin.[45, 53, 54]

The Ohio Experiment Station[55] shows that the inclusion in the ration of riboflavin carriers, such as alfalfa meal, dried skimmilk, dried whey, autoclaved yeast, dried liver, or wheat germ, caused an increase in the hatchability of eggs. The differences in hatching will depend upon the amount of riboflavin present. This difference may be very striking as, for example, 8.0 per cent hatchability from a ration containing none, as compared with 84.8 per cent from a ration containing 3 per cent of liver meal.

Experiments at Cornell,[56] California,[57] Wisconsin,[58] and Canada[59] show that riboflavin is required by hens in order that they may produce eggs which will hatch. The developing chick embryo dies when an insufficient amount of the vitamin is deposited in the egg. The dead embryos are smaller than normal, show curled toes, incomplete absorption of yolk, retarded growth of down, shortened legs, and a slightly edemic condition of the neck. Myelin sheath degeneration occurs in the peripheral nerves. A smaller amount of riboflavin is required for egg production than for hatchability. The riboflavin content of eggs is determined by the amount of riboflavin present in the hen's diet. Eggs of highest riboflavin content can be obtained only by feeding hens a diet rich in this vitamin. The degree of yellow coloration of the egg white is evidence of the richness of the hen's diet in riboflavin. Hens require about 230 micrograms of riboflavin per 100 grams of feed in order to produce eggs that will hatch well.

Hens may lay well on rations inadequate in riboflavin, but riboflavin supplements are needed for increased hatchability. The riboflavin requirement for good hatchability can be met by including such feeds as milk products, yeast, liver meal, alfalfa

yet identified or understood affect hatchability. Some of these have already been suggested.[68] Considerable evidence also indicates that some factor present in animal protein feeds,[69] particularly fish products, and built-up litter[70] is necessary for best hatchability and growth of the resulting progeny.[71]

Experiments at the Iowa Station[72] show that when the ration was made up of single cereals, hatchability was best with eggs from wheat-fed birds, next best for those fed oats, with eggs from those fed corn and mixed grains being approximately equal. The hens fed the wheat or oats rations produced chicks with more vigor than chicks from hens fed corn.

Experiments in Canada[73] show that hatchability is decidedly greater in eggs from hens fed a combination of cereals rather than one alone; also that improved hatchability as a result of the feeding of milk or liver meal or a combination of these protein supplements or as a result of summer sunshine and/or grass range manifests itself in a reduction in anemia, chondrodystrophy, and teratological monsters.

Landauer[1] reports that it has been claimed by Koch (1935, 1936) and Westermayer (1936) that the feeding of follicular hormone to laying hens materially increases the hatching quality of eggs. Extensive tests by Prüfer (1936), however, failed to substantiate any effect of follicular hormone on hatchability.

DIETARY STANDARD FOR BREEDERS

Considerable variation will be found in the recommendations from various sources concerning the requirements for the breeding ration. As a summary of all evidence to date, the probable dietary requirements or standards for breeders are indicated by the Committee on Animal Nutrition of the National Research Council[74] as given in the accompanying tabulation. The figures do not include margins of safety to compensate for possible losses of vitamins during feed processing, transportation, and storage and for variations in feed composition and in environment. In earlier reports the National Research Council suggested allowances which included margins of safety of 66 per cent for vitamin A, 50 per cent for vitamin D, and 20 per cent for the water-soluble vitamins.

To meet the requirements of a breeder ration the accompanying formula pattern on page 423 is suggested for a breeding mash to be fed with grain.

REQUIREMENTS* OF BREEDING HENS

Total protein, %	15
Vitamins	
Vitamin A activity (U.S.P. units)†	2000
Vitamin D (I.C.U.)‡	225
Riboflavin, mg.	1.7
Pantothenic acid, mg.	4.2
Pyridoxine, mg.	1.3
Folacin, mg.	0.16
Minerals	
Calcium, %	2.25§
Phosphorus, % ‖	0 6
Salt, %¶	0.5
Manganese, mg.	15
Iodine, mg.	0.5
Amino acids, %	
Lysine	0.5
Methionine**	0.53
or	
Methionine	0 28
Cystine	0.25
Tryptophan	0 15

* In percentage or amount per pound of feed

† May be fish oil vitamin A or pro-vitamin A from vegetable sources.

‡ International chick unit

§ This amount of calcium need not be incorporated in the mixed feed inasmuch as calcium supplements fed free choice are considered as part of the ration

‖ A portion of the phosphorus requirement must be supplied in inorganic form All the phosphorus of nonvegetable feed ingredients is considered to be inorganic Approximately 30 per cent of the phosphorus of vegetable products is nonphytin phosphorus and may be considered as part of the inorganic phosphorus required

¶ This figure represents added salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content

** Cystine will replace methionine as long as the ration contains not less than 0 28 per cent methionine

TENTATIVE REQUIREMENT

Vitamin B_{12}	0 002 mg per lb

RECOMMENDED FORMULA PATTERN FOR BREEDING MASH

	Lb./ton
High-energy grain products (corn, wheat, wheat red dog flour, milo, oatmeal)	500 +
Medium- and low-energy grain products (oats, barley, wheat flour middlings, standard middlings, bran)	0-800
Vegetable proteins (soybean meal, corn gluten meal, peanut meal)	300-400
Animal proteins; minimum levels (fish meal, fish solubles, meat scraps)	100-150
Other B-vitamin carriers (dried milk products, dried yeast, dried distillers' solubles, fermentation solubles)	150
Dehydrated alfalfa meal	100-150
Additional riboflavin* (if needed)	+
Additional vitamin B_{12}* (if needed)	+
Additional vitamin A* (if needed)	+
Vitamin D_3 (feeding oils or D-activated animal sterols)	+
Calcium and phosphorus supplements (steamed bonemeal, dicalcium phosphate, defluorinated phosphate, limestone)	100
Salt	20
Manganese sulfate (65% feeding grade)	0.5

* Refers to the use of riboflavin supplements, vitamin B_{12} supplements, and vitamin A sources of guaranteed vitamin content or other vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients.

REQUIRED COMPOSITION

Protein, %	20
Calcium, %	2-2.5*
Phosphorus	
Total %	1.2
Available %†	0.8
Vitamin A, I.U./lb.‡	6600
Vitamin D, I.C.U /lb.	680
Riboflavin, mg./lb.	2.1
Vitamin B_{12}, μg./lb.§	3-4

* Free choice feeding of oystershell or other calcium supplement recommended since this level of calcium will not meet full requirements.

† Approximately 30 per cent of the phosphorus of vegetable products is non-phytin phosphorus and may be considered as part of the inorganic phosphorus required.

‡ If corn constitutes half of scratch grain mixture, the level of vitamin A in the mash can be reduced by 1000 I.U./lb.

§ Refers to vitamin B_{12} supplied by fish products, meat scrap, and vitamin B_{12} supplements.

VALUE OF FEEDS OF HIGH VITAMIN CONTENT

Numerous experiments have been reported indicating a favorable influence upon hatchability when the ration included such feeds of high vitamin content as cod liver oil, yeast, milk, and various forms of green foods (including grass range).[11, 14, 75-77] They were effective because they made up nutritive deficiencies and thus balanced the ration.

In northern sections and where birds need to be confined, there is likely to be a deficiency of sunshine during the winter and early spring. Therefore most trials indicated benefits in hatchability when cod liver oil, cod liver meal, or liver were used.[14, 76, 78-81] The differences were usually not maintained when the birds got outdoors. The increase also was greater when the fertility was low, indicating that the birds were not in the best physical condition.

Reports from Canada[79] showed an average increase of 10.3 per cent of chicks alive at 5 weeks of age where cod liver oil was fed to the hens. Holmes[81] reported increased viability of chicks from hens fed cod liver oil.

A very definite correlation has been found between the yolk color of the egg and the intensity of the pigment in the shanks of the chick.[82] In feeding trials showing the effect of pimiento pepper, the Georgia Station[83] reported a better hatch and stronger chicks from hens receiving pimiento.

NUTRITIONAL FACTORS AFFECTING FERTILITY

In general, fertility is not influenced very much by the different nutrients even though hatchability is affected. A restriction of calcium and a lack of vitamin E decreases fertility When rations deficient especially in vitamin A were fed, the Oklahoma Station[84] reported that the males that were on the most deficient rations produced fewer sperms, on the average, than those on more desirable rations.

RELATION OF CONDITION AND HATCHABILITY

The physical condition of the hen produced by feeding and environment has an important effect on the hatching quality of the eggs and the vigor of the chicks. To obtain the best results, breeders must be managed so that they are kept in good physical condition, not only during but also before the hatching season.

When a bird becomes sick, hatching results will become poor

and remain poor until the bird gets back into condition, as shown by the hatching records of a flock of hens at Cornell University[85] in which there was an outbreak of roup. The birds that were not affected showed constant good production and steady hatchability during March, April, and May. The hens that were sick in February showed unsatisfactory hatching until the latter part of March and continued good hatching during April and May. For the individuals that were sick in March, the hatchability early in March, before the sickness, was over 70 per cent, which rapidly fell to 50 per cent and less during and after the sickness. After the sickness, hatchability showed some improvement.

Weight can be used as an indication of health. Loss of weight in females affects hatching adversely. The effect is most noticeable at the time when the birds reach their lowest level in weight, or just after it, and when incubation conditions are unfavorable. In a study of individual hens, it was generally found that hens gaining in weight or maintaining their weight gave the best hatching results while those losing in weight had the poorest hatchability.

Shank color is another indication of condition, particularly when applied to hens just previous to and during the hatching season. Those with yellow color in the shanks might show better hatches than those with faded shanks because the presence of pigment indicates a better surplus of fat and possibly vitamins. The ability to recover pigment quickly and to retain it under heavy production is probably an indication of metabolic efficiency, resulting in a better-nourished individual.

Production, both as regards intensity at the time the eggs are saved and immediately previous to the incubation season, may have a relation to hatching results. Many references may be found in the literature. Some indicate an adverse effect; others show that there is no relation between intensity or numbers of eggs laid and hatching.[86] Where hatching results are influenced by production, it may be due to the fact that very intensive production and long periods of production previous to the hatching season make it more difficult to maintain the weight and condition of the birds.

However, production is not necessarily detrimental if the condition of the hen is not affected adversely.

Shell color[87] in brown egg laying breeds has been reported as being related to hatchability. Hatchability is in favor of the darker colored eggs. It has also been shown that darker brown egg shells are stronger and thicker than lighter brown egg shells.

MANAGEMENT OF BREEDERS

Hens that are used for breeders must be given special consideration, beginning the previous fall, particularly where early season hatching is to follow. The best producers are those that continue to lay late in the fall. Fall production can be stimulated by wet mashes, milk, and lights in order to get the benefit of high egg prices.

REST FOR THE BREEDERS. However, after a season of heavy production the breeders need a period of rest or vacation while they grow their new set of feathers, regain any lost weight and vitality, restore the color to their shanks, beaks, and skin, and store up in their bodies such reserves as vitamins, minerals, and possibly other essentials.

It is also advisable not to encourage production too late in the fall so that the birds can get well along into their molt by the time severe cold weather sets in. For Central New York conditions, production should not continue beyond November. The exact date when the birds should be thrown out of production and into the molt will depend upon the date the first chicks are wanted, the condition of the birds, and to a less extent on the season.

Artificial control[88] of egg production by restricted feeding and restricted lighting during the summer months is possible and such control may be used as a means of increasing the number of fall chicks which may be hatched from hens.

When a hen has her new feathers well grown, she is ready to go to work again Some birds will be ready sooner than others Two months is a safe average If the hens finish the laying year in prime physical condition, well fleshed, and heavy, the strain of molting will not be severe. They will get their feathers back quickly. Birds that have "laid themselves out" and are thin will need more time They must build up their weight as well as grow new feathers. For such flocks a longer rest period may be needed.

WHEN TO STOP PRODUCTION When should the birds of a flock in average physical condition be thrown out of production? That will depend upon the time the first chicks are wanted. Let us assume that the first chicks are to be hatched on March 1 First, allow the 2 months of rest, as indicated above, at the end of which time the lights will be turned on or the length of day increased in order to bring up the production. Allow one month before saving eggs (2 weeks to get the hens started and another 2 weeks for them to get up to 50 per cent production or better)

Good hatchability is not usually obtained until production has reached a more or less steady level. Then, saving the eggs for one week plus 3 weeks for incubation makes a total of 4 months from the time the rest period starts to the time the first chicks hatch. Hence, for March 1 chicks, the prospective hen breeders should not be kept in production later than November 1. As pointed out above, in a well-conditioned flock, this time might be somewhat shortened. For instance, they might lay up to November 15 and still give a good hatch for March 1.

HOW TO STOP PRODUCTION. There are several methods of stopping production. One is to omit artificial illumination. Another is to move the birds to different quarters. A third method is to change the feeding. Eliminate wet mashes or milk if they are being fed, or omit the dry mash for a short time and feed more grain. In some flocks it may be necessary to resort to all these practices.

When the birds stop laying and molt, the amount of grain should be increased. Heavy grain feeding should be practiced during the winter since this helps to build up the body weight. As soon as laying has stopped and the molt started, keep the grain in hoppers open all the time. It is not desirable to let the breeders become overfat. However, there is little danger of this unless the birds are several years old. In that case, it may be advisable to feed the grain in clean, dry litter to induce more exercise. Keep the dry mash always available in open hoppers.

MAINTAINING HEALTH AND VIGOR OF BREEDERS

WINTER CARE OF THE MALES. There is often a real problem of feeding involved where the males are kept with the hens during the winter. On range, the cockerels have had full access to the grain mixture. For a time, the same condition exists in the breeding pen. Then the grain might be restricted to induce the hens to eat more mash. The males do not take so readily to the mash and might not get enough grain to keep them in good condition because of the shortened grain-feeding period or because they are too gallant. The result is that they become thin and inactive, with consequent poor fertility.

There are several ways to avoid this difficulty. One is to fasten boxes of grain along the wall out of reach of the hens but where the males, with their greater height, can reach them. The boxes must be narrow so that the hens cannot get a footing on them. Another plan is to divide the males into two groups and alternate these groups in the pen and in a coop, out of sight of

the rest of the flock, where they can catch up on their eating.

Frozen combs and wattles often indispose the birds so that they do not eat enough. One cause of freezing is the wetting of the wattles while drinking. Fountains with narrow drinking ledges will largely overcome this trouble.

Studies at Cornell have shown that cockerels attain their greatest body weight when exposed to 9 hours, or less, of light daily. This fact is useful for poultrymen who house their breeding males in pens of pullets, exposed to 13 or 14 hours of light daily during the winter, and find it difficult to keep them in good physical condition. Males will attain greater weight and better condition if they are not exposed to supplementary illumination until the breeding season, or about 3 weeks before they are to be placed in the breeding pens, when they should be exposed to 13 hours of light daily.

GENERAL SUMMARY

Any factor which affects the condition of the bird will affect the hatching results. Therefore a deficiency in any of the nutrients can be expected to influence results.[89] A lack of the vitamins, especially, has produced lower hatchability.

Assuming that the stock has been carefully selected for vigor and vitality and breeding performance, and that environmental conditions are correct, it will be more nearly possible to "count your chicks before they are hatched" by allowing the hens a proper rest, giving them access to sunshine, and providing a complete ration by feeding a variety of cereals, animal protein feeds, green food, and other vitamin concentrates.

RATIONS FOR BREEDERS

The requirements for some nutrients are greater for breeders than for layers. Still it is possible to formulate a variety of rations for this purpose. Some representative recommendations for breeder rations will be found in the Appendix. (See page 572.)

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CHAPTER 15

FATTENING OR FINISHING OF POULTRY

Fattening or finishing poultry for the table is one of the oldest practices of poultry husbandry. Brown[1] says:

> For a long period of time, among the dainties or finer dishes for the table, fowls of various kinds have been recognized as holding a leading place. Even as far back as the days of Solomon we find in Scripture references to "fatted fowls," though whether these words apply to ordinary poultry is a point which has led to some discussion. We may, however, leave this controversial subject on one side, for there can be no question that 4000 years ago the ancient Egyptians crammed their geese, and probably were the originators of the cramming system. A drawing, copied from one of the tablets in the Pyramid of Sakkara, represents a man engaged in the work of cramming geese by means of pators, or boluses, of food.

Wright's Book of Poultry[2] indicates that Pliny mentioned the inhabitants of Delos as the first to prepare fowls artificially for the table, by which no doubt cramming is intended, and in his time there is no doubt that the luxury-loving Romans patronized crammed poultry extensively.

Dickson[3] in his book on the general management of poultry gives information concerning early fattening practices.

Poultry has been fattened in Europe for centuries. Furthermore, the industry has been more or less localized in certain sections in the different countries. In England the counties of Surrey and Sussex have long been famous for their fatted chickens. In France the industry has been centered around La Bresse, and in Belgium around Malines.

OBJECTS OR ADVANTAGES IN FATTENING

Fattening should be looked upon as a finishing process. The carcass is improved or fitted for slaughter. In the process, an excess of nourishment is transformed into fat. The improvement is both external and internal. In the first place, the size of the bird is increased. The actual gain in weight will depend upon various factors which will be discussed later. Externally,

the appearance of the bird is improved by making it more plump. The color of the flesh can also be influenced, making it paler or yellower according to the market preference.

Not only is the size increased, but usually the proportion of edible parts is enlarged. Harshaw[4] states that fattening resulted in about a 6 per cent increase in the total edible portion and that 73 per cent of the gain in weight during fattening was represented in the edible portion of the bird. The percentage of breast muscle and leg muscle decreased with fattening while the percentage of the remaining edible portion increased. The increase in fat plus water, during fattening, was from about 85 to 92 per cent of the gain in the total edible portion. In the younger birds, the increase was greater in water than in fat, but in the oldest birds the reverse was true. The increase in protein was relatively small, and its ratio to the total edible gain tended to decrease with the age of the birds.

Poley and associates[5] noted a tendency toward an inverse relationship between the fat and moisture content of edible meat. In comparing battery and range methods of finishing, an increase was found in the percentage of fat in both fryers and roasters finished in the battery. The corn- and wheat-fed fryers and roasters had significantly more total edible meat on the carcasses than the birds receiving barley. The wheat- and barley-fed fryers and roasters had a somewhat higher percentage of light meat than those receiving corn. The corn-fed fryers and roasters showed a consistent tendency to deposit more fat in the light meat, dark meat, skin and subcutaneous fat, and the abdominal fatty tissue than the other two groups. They were followed in order by the wheat- and barley-fed groups, with significantly more fat in the carcasses of the corn-fed than in those of the barley-fed group.

Fraps[6] reported that the substitution of cottonseed oil for part of the corn meal in a standard ration produced chicks with a much higher fat content. Substitution of feeds with a lower productive energy for the corn meal also produced chickens with a lower fat content. He suggests that there is probably an optimum fat content of the ration to produce chickens of good quality.

One of the important results is the internal effect or improvement in the quality of the flesh. Tiny globules of fat are distributed through the muscles. More intercellular material is formed, which softens the tissues and produces a "marbling" effect. This results in greater tenderness, more juiciness, and better flavor.

The increase in weight, as well as the external and internal improvement, should secure an increase in price per pound as compared with the unfinished chicken.

METHODS OF FATTENING

Various methods of fattening birds are practiced, varying from the highly intensive to the less intensive as follows: (1) stuffing or cramming; (2) crate fattening; (3) pen fattening.

STUFFING OR CRAMMING. In this method the birds are force-fed. It is practiced largely in European countries. The birds are closely confined in small and usually darkened coops. They are fed forcibly once or twice a day, which may be done in a number of ways.

1. Cramming by Hand. The food is made into a stiff paste and formed into pellets $\frac{3}{4}$ to 1 inch long and $\frac{3}{8}$ to $\frac{1}{2}$ inch thick. These pellets are dipped into whey or milk, inserted into the mouth, and forced into the crop. In France, masses of food instead of pellets are sometimes used. Obviously, this method involves considerable labor. It is the method usually employed in "noodling" geese.

2. Cramming by Funnel. This method was used largely in Normandy. The food is in liquid form. A specially made funnel is inserted into the gullet and into the crop. The cream-like ration is spooned into the funnel until the crop is full.

3. Cramming by Machine. The cramming machine consists essentially of a hopper or reservoir for the feed and a force pump, controlled usually by a foot pedal. A long tube, extending from the pump, is inserted into the crop and the food forced into the crop until it is full.

Cramming puts the final finish on the birds. In Sussex (England), the birds are placed in cages out of doors and fed for a week or 10 days from troughs. Then they are placed in sheds and crammed for another period of time, usually about 10 days.

Schmidt[7] reports that cramming showed better utilization of feed than free fattening.

CRATE FATTENING. This method is used largely in the United States and Canada. Gutteridge and coworkers[8] reported the crate feeding of capons as being definitely superior to pen feeding. They also reported that crate fattening was greatly superior to ordinary range rearing methods for the production of gain, increase in fat, and grading of the dressed bird. They concluded that crate feeding was the most efficient method and

was productive of very high quality stock; that caponizing for market was the next most efficient method and was very economical because of lower feed requirement during the rearing period and because of the high degree of fat even when killed off range; and that the killing of cockerels for market directly off range was the least economical procedure.

The birds are placed in small crates or coops. The crates are usually constructed of wire or slats and have wire bottoms. *The feed troughs should be suspended outside.*

PEN FATTENING. In pen fattening, the birds are confined to a small coop with or without yards. The birds are allowed more floor space than in crate fattening, usually about 2 square feet for old birds. For best results, the flock should be limited to 20 or 30 birds. They can be kept in pens for a longer period of time than in crates. This method is often used for broilers or young stock.

PRINCIPLES

The success of the fattening process, like success in other branches of the poultry industry, depends upon a combination of factors.

STOCK. In the first place, the birds must be healthy. Birds "off condition," of low vitality, or infested with parasites cannot be fattened profitably. Furthermore, the birds must be capable of fattening. Hens in prime laying condition will not gain by fattening.

The general-purpose and meat breeds are best for fattening purposes. However, Leghorns make good gains up to $2\frac{1}{2}$ to 3 months.

QUARTERS. The pens or house in which the birds are fattened should be comfortable. They should be reasonably warm in winter and cool in summer. However, Gutteridge and O'Neil[8] reported that the temperature condition had no marked effect upon the gains made, the lowest temperature (average 36.4° F.) showing a tendency to superiority. A greater feed consumption was evident at the lower temperature. Takita,[9] comparing fowls fattened in winter (average temperature 5° C.) and in summer (average temperature 27° C.), indicated that the body fat of the former contained only about $\frac{1}{4}$ as much free fatty acid but more liquid fatty acid than of the latter. Clean quarters are necessary to insure keen appetites. The place should be quiet and free from disturbance or excitement. Subdued light will help to keep

the birds quiet. The object throughout is to restrict exercise and activity since they develop tough and hard muscles.

LENGTH OF FATTENING PERIOD. The length of time depends upon keeping the birds on feed and the gains that are made. In crate fattening, gains will usually be made for 12 to 15 days. In pen fattening, the period is somewhat longer, about 2 to 3 weeks. The cost per pound of gain is lowest the first part of the fattening period, but the process may be lengthened beyond the period of cheapest cost as long as gains are being made, in order to produce the best quality of flesh. The size of the chicken also influences the most efficient length of fattening period. Jull and Maw[10] indicate a period of 10 days for large-sized birds, such as Plymouth Rocks and Rhode Island Reds (weighing 4 pounds or over), and 14 days for medium-sized birds (weighing about 3 pounds). Gutteridge and O'Neil[8] conclude that, for well-reared cockerels of roaster age, 2 weeks of fattening gave greater and more economical gains and fat increase than 1 week, but 3 weeks of fattening was not justified by the results obtained.

MANAGEMENT PRACTICES. In order that they will eat the fattening ration greedily, birds should not be fed for the first 24 hours after they are placed in the crates or the pens.

The total food intake is related to the number of feeds per day. When comparing two, three, and five feeds daily, Maw[11] reports that two feeds daily for 10 days gave definitely smaller gains than three or five feeds. The figures indicate that birds getting a larger number of feeds per day convert more of the feed consumed into gain. On the other hand, Gutteridge and O'Neil[8] report that, in crate fattening, two feedings daily were as efficient as three feedings for weight gain and fat increase.

For fattening on the farm, it has been found that feeding twice a day has given satisfactory results because the feedings can be more nearly equally spaced. There is less danger of overfeeding when feeding two times a day. The birds should be fed all they will clean up readily morning and night. Great skill is required to feed for best results in fattening, as the feed should be removed just before the bird has eaten enough.

If at any time the birds go "off feed," one feeding should be omitted. Clean pails and troughs will help to prevent this condition.

Sometimes feather picking develops. This may be overcome by feeding fresh meat or extra meat scrap. Also methods of handling the poultry before fattening should be better, and starving should not be too long.

FEEDS AND RATIONS

Fattening rations are usually restricted and need not be so complete as rations for other purposes, since the birds are not dependent upon them for a long period of time.

Whole or cracked grains are not used in fattening rations, except possibly as a light feeding in pen fattening. In a test conducted in Missouri[12] birds fed on shelled corn gained 1/5 pound in 3 weeks while birds fed on corn meal and buttermilk gained 1/2 pound in 2 weeks. The cost per pound of gain on the whole grain was 4 to 8 times as much as on the finely ground grain and buttermilk.

Grit, shell, charcoal, salt, and other accessory feeds are unnecessary and only add to the labor and expense. Green food usually is also nonessential, although sometimes it is given once or twice a week as an appetizer. Usually water is not given as such, but it must be kept in mind that less water is needed in cool than in hot weather. In very hot weather it may be necessary to give the birds water to drink. Gutteridge and O'Neil,[8] however, reported that the gain in weight of Barred Plymouth Rock roosters was increased when the birds were permitted access to drinking water between feedings.

The ground grains are mixed with the liquid until the feed runs readily in hot weather and drips freely in cool weather. Hence more liquid is used in hot weather. It usually takes about 1 pound of dry feed and 2 pounds of buttermilk to produce a sloppy mixture. In some places, particularly England, the feed is allowed to stand a number of hours to produce fermentation.

FEEDS. A variety of feeds are used in fattening rations. In the main, they are fairly concentrated and usually finely ground. In England the fattening ration is composed largely of ground oats; in Belgium buckwheat meal is used; in France the ration is made up largely of buckwheat meal and barley meal; in the United States corn meal is most often used.

Cereals and By-Products. Maw and coworkers[13, 14] show that the individual cereals, yellow corn, wheat, oats, and barley, as ground whole cereals for fattening purposes, vary in their effect on the gains made and the quantity and nature of the fats produced in the growing chicken. These grains influence the amount of fat deposited in the body in a definite order, corn being superior, with wheat, oats, and barley following in this order. The color of the fat in the carcass and the percentage of fat in the edible meat are also influenced by the cereal fed.

Results definitely show that the different cereals cause the

deposition of fats in different manners. Corn meal causes a high percentage of the total body fat to be deposited in the flesh and less fat in the abdominal cavity and in the skin of the bird, whereas the cereals, barley, oats, and wheat show the reverse in varying degrees. The corn flesh showed the highest flavor and was moist, whereas the wheat flesh lacked flavor and was dry. The barley and oat flesh were intermediate.

Such factors as the age of the stock being fed and the length of the feeding period have a bearing on the results obtained. The ground whole-oat ration was found to equal ground hull-less oats in feeding broiler stock. With mature roaster stock, wheat and corn were found to be superior to oats in a 21-day feeding period, although on a 7-day period wheat and oats were of equal value, with wheat superior to corn or barley. The single cereals were equal to the best combinations of two or three cereals. No significant differences in the distribution of fat in the body were found, as between the single or combined cereals with 5-pound roaster stock. The body fats were found to differ widely in iodine value and color, according to the cereal used. Maw[14] reports the iodine value of fat from corn-fed birds to be 67.4, from wheat-fed birds to be 65.7, from oat-fed birds 63,2, and from barley-fed birds 56.5

Gutteridge and coworkers[8, 15] report that corn gave superior gain to all other feeds (wheat, oats, barley, cooked potatoes) Ground buckwheat gave as great gains as yellow corn but required considerably more feed per unit of gain and was inferior to corn in its ability to increase fat. Ground oats and ground barley were of approximately equal value. However, ground hulled oats, when coarsely ground, were superior to ground yellow corn for fattening Jeffrey[16] states that corn proved to be superior to oats in improving the eating quality of roasters under conditions of pen fattening. The oat-fed birds, however, were superior in desirable flavor of fat McMurray[17] indicates no significant difference in gain between Sussex ground oats and barley meal. Poley and associates[5] state that, when judged by the amount of feed required to produce a unit of gain in body weight of fryers during the growing period, wheat was most efficient, followed in order by barley and corn. In growing rations for roasters, the gain-feed ratio was practically the same for corn and wheat, but somewhat more barley was required for the same gain in body weight. In the finishing rations tested, corn, wheat, and barley ranked in this order of efficiency

In groups of Light Sussex cockerels, fed for 12 days on a ra-

tion of 12 parts of dried skimmilk and 88 parts of Sussex ground oats, maize meal, or barley meal, Cruickshank[18] reports that the softest fat was produced by oats in mature birds and by maize in immature birds. Barley produced harder fat in both. Maize had no detrimental effect on the consistency of the fat in either mature or immature birds, when fattening was rapid and live weight gain satisfactory, but it produced a harder fat than was produced by a ration of mixed cereals with a protein supplement.

Gutteridge and O'Neil[8] report an associative complementary effect brought about by combining grains (ground oats and yellow corn). They also report that fine grinding of the grains was slightly superior to coarse grinding.

Corn oil meal is a desirable ingredient for fattening rations. It has the ability to absorb large quantities of liquids, and it has been reported to be able to hold two to seven times its weight in liquid. The fat in the corn oil meal also helps to give the bird finish.

Other feeds used are wheat middlings, low-grade flour, oat meal, oat flour, pea meal, barley meal, buckwheat middlings, buckwheat flour, graham flour, and hominy. More corn meal can be used in cool weather. The amount of middlings and ground oats are advantageously increased in hot weather, owing in part, perhaps, to the ability of these feeds to retain more water. Feeds vary widely in their nature to absorb water. Maw[19] indicates that the following feed-water ratios have been found to exist: Corn, 1:1.3; barley, 1:2; oats, 1:2.5; wheat, 1:1.75; mixtures of any two of these cereals, 1:1.5; mixtures of any three of these cereals, 1:1.65; cereal mixtures plus supplementary fats, 1:1.6. A study at the Kansas Experiment Station[20] gives information on the milk-absorbing capacity of eight single-ground grains and two-ground grain mixtures. When the grains were allowed to soak in milk at room temperature for 24 hours, the quantity of milk absorbed ranged from 21.1 gallons per 100 pounds of ground milo to 67.1 gallons per 100 pounds of ground whole oats, all others falling within a range of 30 to 45 gallons. There was no apparent relation between the moisture content of the grain and the amount of milk it would absorb.

Potatoes. Experiments reported from Germany[21] indicate that potato flakes, with an adequate protein supplement, may be used as the chief component in the ration. Potato silage and steamed potatoes may also be fed so long as the protein ratio is adjusted. It was also reported to be uneconomical to use po-

tatoes in fattening young cockerels as compared with swine. In particular instances, however, when poultry brings a correspondingly better price than pork, feeding potatoes may be profitable. Potato flakes are more economical to use than old stored potatoes in which much of the nutriment may be lost. Gutteridge[8] reported that potatoes, either raw or cooked, and mash (equal weights) were definitely inferior to mash alone.

Sugar Beets. Sugar beet slices[21, 22] gave good results in fattening experiments in Germany. The authors concluded that, in the fattening food, up to 50 per cent of dried sugar beet slices can be used but they must be cut extremely small. Their food value is equal to that of crushed barley.

Milk. Liquid buttermilk and skimmilk have been considered an essential ingredient of all good fattening rations. They seem to whiten and soften the flesh. However, experiments at the Missouri Station[23] show the value of other forms of milk for fattening poultry. The most satisfactory gains and highest percentage of initial weight packed were obtained when 10 per cent of dried skimmilk was fed; the lowest dressing loss was obtained when 5 per cent was fed. At the feed prices used, 5 per cent of dried skimmilk and liquid buttermilk produced the cheapest gains; condensed buttermilk produced the most expensive gains. Condensed buttermilk produced the highest quality birds, with 93.6 per cent No. 1; 10 per cent dried skimmilk ranked next with 90.4 per cent No. 1 birds. Experiments in Germany[24] also showed milk as the best protein addition for fattening.

Milk is best used as a moistener for the fattening mash. Trials in Canada[25] showed that dry mash and milk fed separately ad libitum, gave much less satisfactory gains than when the two were mixed in the proportions of two parts skimmilk to one part of mash and supplied as two feeds per day. But the latter method gave optimum results only if the birds were kept in crates. Skimmilk, as a mixer[8] for a fattening mash, gave very greatly superior gains to water and was also somewhat more efficient in the production of fat. The benefit of skimmilk was not accounted for by mixing pure crystalline riboflavin with water.

Protein Concentrates. With a mixture of two or more staple grains, sour skimmilk is necessary to produce the best results. Without milk, meat scraps can be used to advantage.[8] Jull and Maw[10] conclude that 10 per cent of meat scrap is justified but 20 per cent is not justified. Where milk is used, meat scrap is unnecessary and its use not justified.

Results at North Carolina[26] indicate that animal proteins could not be replaced by vegetable proteins, and in tests lasting 1 week substantially equal gains followed the use of digester tankage, blood meal, soybean meal and dried milk, and meat scrap. Experiments in Germany[27] showed that fresh blood proved advantageous for fattening ducks and cockerels.

Fats. Fat or tallow is sometimes added to the ration. In England fat, preferably mutton fat, is included during the last 10 days of fattening. However, experiments at the South-Eastern Agricultural College[28] show no appreciable difference in the gains produced by mutton fat or palm oil. In fattening trials in Canada[8, 25] the addition of 5 per cent of mutton fat to a fattening ration increased the gain by 18 per cent, the efficiency of use of feed by 27 per cent, the increase in percentage of fat by 15 per cent, and the percentage of A grade birds by 17 per cent. A desirable fat of firm texture was produced. A level of 10 per cent of mutton fat had a tendency to impart its flavor to the fat of the bird. Corn oil, while giving very satisfactory gains and fat increase, did not maintain either gains or increase for as long a period, and a fat was produced which was decidedly soft, even to the extent of producing some fluid fat in the abdomen of some birds.

Voitellier[29] states that the nature of the fat in the feed will influence the nature of the fat in the animal and thus determine the taste, odor, and culinary quality of the flesh of the hens. Cruickshank[30] showed that the ingestion of high percentages of saturated fatty acids in the form of palm kernel oil and mutton fat definitely increased the degree of saturation of the mixed fatty acids of the depot fat, while the ingestion of unsaturated acids in the form of hempseed resulted in a marked and rapid increase in unsaturation.

Maw[14, 19] reports on the feeding of supplementary fat as follows. Hard fats (mutton fat) are difficult to feed, whereas soft fats, such as vegetable oils, are easily incorporated with the meal mixtures. Certain oils affect the flavor of the meat. Corn oil produces a very satisfactory flavor, whereas cotton oil practically causes a loss of flavor, or a very unpalatable, flat-fat flavor. Peanut oil produces a sweet flavor in the meat. The effect of feeding additional fat in the form of crude corn oil is to increase the amount of fat in the skin and the abdominal fatty tissue. Such results make for a better finish. Small stock, such as broilers, show the effect more strongly than large roasters.

Some quality loss has been reported due to bile stain in stor-

age. Maw and Nikolaiczuk[31] report a bile depletion method, involving preslaughter fat feeding, to eliminate liver stain in stored dressed poultry. Preliminary experiments demonstrate that the inclusion of approximately 25 per cent of refined cottonseed oil, added in the final or last two feeds prior to slaughter, is effective in depleting bile volume sufficiently to overcome extensive stain damage in dressed broiler and roaster carcasses during storage.

Miscellaneous Feeds. The Hawaii Station[32] reports that fattening rations containing avocados, bananas, and sweet potatoes, mixed with wheat middlings, yellow corn meal, or with both, proved to be efficient for the production of broilers and roasters of fine quality.

Green cut bone has also been used to advantage in small amounts as an occasional appetizer.

Gutteridge and O'Neil[8] report that the addition of bone meal to the fattening mash, at a level of 5 per cent, has no beneficial effect upon gains, fat increase, or whiteness of the dressed carcass.

HORMONES. Hormones have been fed for their effect upon the carcass. The estrogenic hormones produced in the ovary cause an increased deposition of fat under the skin, in the abdominal cavity, and in the muscles. The estrogenic hormones should be of greatest use in fattening and finishing male fowls. Adult females are less likely to be improved as most of them are supplied with their own natural estrogen. The treatment should be useful for broilers of both sexes since they ordinarily grow too quickly to accumulate much fat.

Lorenz[33] reported that tissues of birds receiving subcutaneous pellet implants of the estrogen, diethylstilbestrol, had striking and consistently greater fat content. Growth was also affected by the treatment. The greatest difference was obtained at 8 weeks of age (after 5 weeks of treatment). The meat quality was improved. This was especially noticeable in older birds, which normally have tough, darkened meat. The treated bird's meat was paler and considerably more tender. Oral administration was decidedly inferior to pellet implantation, but it has certain advantages. Turkeys also showed a distinct increase in abdominal fatty tissue. The maximum effect was produced after 44 days of treatment.

In trials at Cornell, in which one pellet (15 to 20 milligrams) of diethylstilbestrol per bird was implanted under the skin of old male fowls and left for 3 to 5 weeks, the treated birds ex-

controlled amounts since growth is depressed and mortality increased as the levels of thyroxine are increased. Combinations[39] of thyroprotein and thiouracil or stilbestrol have also been shown to be effective.

THE RATION. Studies at the Animal Nutrition Institute, Cambridge, England,[40] indicated that the principal change in the composition of adult fowls during fattening was an increase in fat content of the body, with relatively small increases in body protein. Rations composed of dried skimmilk and Sussex ground oats in proportions of 5:95 (12.47 per cent protein) were utilized with equal efficiency by fattening fowls. Results reported from Canada[14,41] also show little effect of the amount of protein on gains in the 21-day fattening period and show that the protein and fat content of the thigh muscle are not significantly influenced by different protein levels in the fattening ration.

In young birds the finishing process involves growth as well as plumping. Hence rations containing a larger amount of protein have given better feather growth and greater gains.

In compounding the ration, feeds should be selected to give a basic reaction. Solun and Schuster[42] indicate that the maintenance of the acid-base balance in the organism is to be looked upon as one of the main factors regulating the appetite of the fowl and determining the results of fattening.

EXPERIMENTAL RESULTS AND GAINS

Increase in weight is one of the results of the fattening or finishing process. The amount which the birds will gain depends upon the age of the bird, the condition of the bird, the method of fattening, and the degree to which the various requirements are met. In growing birds, more economical gains are made during the earlier periods. The relation existing between the increase in live weight and the consumption of food is shown in the following data from Italy.[43] For each kilogram increase in the live weight of Malines Coucou, approximately 2½ kilograms of feed were required for chickens under 2 months; 3 kilograms of feed for chickens of 2 to 3 months; 3.9 kilograms for chickens of 3 to 4 months; 4.17 for chickens of 4 to 5 months; 4.80 for chickens of 5 to 6 months; 6.60 for chickens of 6 to 7 months.

Broilers show the greatest gains since they are still growing rapidly. The North Dakota Station[44] reports cockerels showing gains of 28 to 38 per cent. The Missouri Station[23] indicates broilers as gaining 24 to 30 per cent, with an average of 26.3

per cent. Results of fattening under the direction of the United States Department of Agriculture[45] show an average gain for broilers of 32.3 per cent. The gains in the case of broilers represent largely growth increases. Well-grown broilers require little or no special fattening. This is particularly true with the high-energy rations being fed at the present time.

Roasters and hens do not make as large gains as younger birds. The Missouri Station[23] indicates gains for roasters of 13 to 15 per cent, with an average of 14.3 per cent; and for hens 13 to 14 per cent, with an average of 13.5 per cent. The United States Department of Agriculture[45] indicates an average gain of 12.1 per cent for roasters and 10.4 per cent for hens.

FATTENING RATIONS

Some typical fattening rations as recommended by a number of experiment stations will be found in the Appendix. (See page 580.)

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CHAPTER 16

FEEDING TURKEYS

The feeding of turkeys, especially the young stock, has undergone considerable change. It is only natural that it should follow in the wake of the advances made in chick feeding. As was also true of chicks, the older methods of feeding were usually complicated and laborious. The following statement taken from the bulletin "Raising Turkeys in Wisconsin"[1] describes the old order.

> For a long time a turkey ration was used that changed in amount, composition, and time of feeding each day. The principal ingredients were cracker crumbs, stale bread, boiled eggs, dandelion greens, lettuce, and milk; and no one ever had any plausible reason for using a ration of that sort. It was just accepted.

At the present time turkey rations are being developed along the same lines as chicken rations. The information gained in the feeding of chickens is being applied to the feeding of turkeys. In fact, many persons have used the usual poultry rations with fairly good success, especially where the turkeys have good range. The chicken rations are not the best, however, since in many respects the requirements of turkeys differ from those of chickens. Turkeys show greater relative gains than chickens, especially early in life. These greater gains are reflected in larger demands for some of the nutrients. This is particularly true for energy, protein, and unidentified vitamins.[2]

REQUIREMENTS OF THE TURKEY RATION

PROTEIN. Most experiment stations now recommend high-protein rations for young turkeys. This no doubt is necessary because of the greater rate of growth. The California Station[3] showed that turkey poults require more protein than chicks. Funk[4] pointed out that turkeys make greater relative gains than chickens and that there is a relation between early and later growth.

In 1932 the Pennsylvania Station[5] indicated the protein requirement of poults, based on the amount of milk consumed by

them, to be 26 per cent for the first two weeks, 21.7 per cent for the third week, and 19.5 to 21.3 per cent for the fourth to eighteenth weeks.

Similarly, results from other sources[2,4-6] show the advantages and necessity of high-protein rations for starting turkeys.

In turkey feeding trials at the Washington Station,[7] in which the birds had free access to both grain and mash, they consumed 19 per cent scratch grain and 81 per cent mash from the twelfth to the sixteenth week, as compared with 72 per cent scratch and 28 per cent mash during the last four weeks of the trial. The protein content of the feed consumed averaged 13 per cent at the end of the twenty-eighth week.

In experiments reported by the U. S. Department of Agriculture,[8] in which mash and scratch were fed ad libitum, with the protein content of the mashes ranging from 18 to 30 per cent, it was found that the ratio of mash to grain consumed varied inversely with the protein content of the mash. During the first 16 weeks, the average live weight of the several lots was, in general, in the same order as the quantity of protein consumed. However, after 16 weeks the gains per 4-week period were not so closely associated with the quantity of protein consumed. The birds fed the mash that contained about 28 per cent of protein weighed the most at all ages after 12 weeks, and those fed the mash that contained about 18 per cent of protein weighed the least at all ages. Between 21 and 28 weeks of age, the turkeys consumed mash and grain in such proportions as to provide a ration averaging about 16 per cent protein. The quantity of protein consumed had no consistent effect on mortality or malformation of leg or breast bones.

The results to date would indicate that for the most rapid and economical gains the protein level of a turkey starting ration should be 28 per cent. After 8 weeks a growing ration containing 20 per cent protein is sufficient. In the later growing period (after 4 months) the protein can be reduced to 16 per cent. The breeding ration should furnish 15 per cent protein.

AMINO ACIDS. Some information has also been obtained concerning the amino acid requirements of turkeys. The arginine[9] requirement has been placed at 1.35 per cent for the starting ration. Approximately 0.8 per cent of the sulfur amino acids[10] were required for optimum growth in a ration containing 24 per cent crude protein. This amount includes a minimum of 0.5 per cent methionine. Methionine may completely replace cystine, but cystine is not changed to methionine.

Lysine[11] is necessary for growth and the prevention of the occurrence of white feathers in Bronze turkeys. The requirement has been placed at 1.3 per cent, although this requirement may be increased under certain conditions.

Methionine and lysine appear to be the limiting amino acids on low-protein turkey poult diets. Supplementing a 20 per cent corn-soybean diet with lysine and methionine has produced growth equivalent to a 28 per cent protein ration.[12]

Approximately 0.9 per cent of total glycine[13] has been reported as the smallest amount which is necessary for optimum growth. Glycine may be concerned with "hock trouble" which occurs in turkeys.

The tryptophan[14] requirement of the poults has been reported as being 0.19 to 0.28 per cent.

MINERALS. A proper amount and a balance of minerals are necessary. For the growing poult, calcium and phosphorus must be furnished in largest amounts. The quantities to furnish will depend somewhat on the amount of vitamin D present.[15] Mussehl and Ackerson[16] report that growing poults are able to adjust themselves to a considerable variation of the calcium-phosphorus ratio. When the vitamin D was withheld, the poults receiving the higher levels of calcium, provided by calcium carbonate, appeared to adjust themselves best to the vitamin limitation.

The calcium and phosphorus requirements[15, 17] vary somewhat depending upon other factors. The rate of growth might have some influence. A smaller amount appears more satisfactory for growth than for good bone calcification. The calcium requirement has been indicated as being 1.6 per cent to 2.0 per cent. A diet containing 0.6 per cent of available phosphorus has given excellent calcification.

The total phosphorus of the ration should not be too high since it might aggravate the occurrence of perosis and decrease growth. However, the ration must have sufficient manganese and choline[18] and niacin to secure proper bone development and prevent perosis.

Usually one-half to 1 per cent of salt is added to turkey rations. Turkeys have been reported to tolerate salt up to 4 per cent of the ration.[19] The other minerals are ordinarily present in sufficient amounts in the average practical ration.

VITAMINS. The same vitamins are necessary for turkeys as for chickens and are supplied in the same feeds. However, special consideration must be given to species reactions or requirements. Turkeys require larger amounts of vitamins than do chickens.[20]

Vitamin A. The vitamin A requirement of poults is higher than for chicks. Sherwood[21] reported that turkeys require twice the amount of vitamin A as do chickens. Poley and Tulley[22] report more rapid gains from birds receiving yellow corn than those receiving white corn. They attribute the difference to a possible vitamin A deficiency due to drought conditions, which did not permit the growth of vegetation.

Hinshaw[23] observed in turkeys receiving various levels of dehydrated alfalfa meal as the source of vitamin A that the percentage of mortality associated with A-avitaminosis varied inversely as the amount of alfalfa in the ration. No mortality due to A-avitaminosis occurred in turkeys receiving either 8 per cent of dehydrated alfalfa meal or freshly cut alfalfa.

The vitamin A requirement[24] of turkey poults has been reported as ranging from 500 to 700 International units per 100 grams of feed.

Vitamin D. In applying the feeding of cod liver oil to turkeys to prevent rickets, it was soon noticed that the turkey's requirement of this vitamin was greater than the chicken's. This was shown by the Kansas workers[25] when they reported that turkeys developed rickets earlier than chicks. Baird and Greene[26] state that chickens weighing 1000 grams or better at 12 weeks required a minimum of approximately 18 U.S.P. units of vitamin D per 100 grams of feed, whereas turkeys weighing 1900 grams or better in 12 weeks required a minimum of 60 to 70 U.S.P. units of vitamin D per 100 grams of feed. Other workers[27] have also concluded that 70 to 100 A.O.A.C. (52.5 to 75 International chick) units of vitamin D per 100 grams of ration seemed to be ample for satisfactory calcification in the poult.

Murphy[28] reported that the requirement for poults appears to be 175 A.O.A.C. (131.25 International chick) units of vitamin D per 100 grams of feed. Jukes and Sanford,[29] using a fish-oil blend as the source of vitamin D, concluded, in 1939, that while the vitamin D requirement of turkeys cannot be precisely stated in terms of A.O.A.C. chick units, the value of 200 chick units per 100 grams of diet was approximately the amount required to support normal development of turkeys to 4 weeks of age. Later they found this to be true for one source of vitamin D but not for two other sources of the vitamin.

The above difference can be explained by later experiments.[30] which show that the source of phosphorus influences the efficiency of vitamin D, that the response of turkey poults to vitamin D from different sources is not the same, and that the poult uti-

lizes certain forms of vitamin D with degrees of efficacy that differ from the chick, and hence vitamin D potency expressed in chick units is not necessarily a true measure of the value of a vitamin D supplement for turkeys.

Robertson, Rhian, and Wilhelm[31] showed that the growth of poults to 4 weeks of age on a ration devoid of vitamin D was in direct proportion to the level of vitamin D in the breeding hens' ration. The effect of the level of vitamin D in the hens' ration upon the response of poults is greater the first two weeks, and thereafter the influence of vitamin D in the poults' ration is greater. Wilhelm, Robertson, and Rhian[32] reported no benefits in egg production or hatchability from the addition of cod liver oil beyond 100 units of vitamin D per 100 grams of ration.

Vitamin E. Vitamin E has also been reported as benefitting the hatchability of turkey eggs.[33]

Riboflavin. Riboflavin deficiency in turkeys is characterized by retarded growth, dermatitis, perosis, and poor feathering.[34] Most turkey rations containing a large amount of milk have given good growth, owing in part to the fact that the milk furnished enough riboflavin. Experiments at Cornell indicated that turkey rations for the first 4 weeks should contain a minimum of 320 micrograms of riboflavin per 100 grams of feed. During the second 4-week period the riboflavin requirement dropped to 200 micrograms. After the turkeys were 8 weeks old, the riboflavin requirement was not greater than 140 micrograms. The quantitative requirements for riboflavin for the first two periods of 4 weeks each were in proportion to the relative growth rate. The riboflavin requirement of turkeys was approximately 25 per cent greater than for chicks at the same age, which represented roughly the difference in the rate of growth of these two species. Jukes,[35] however, did not find such difference but reports that the riboflavin requirement for poults is about the same as for chickens.

The Nebraska Station[36] reported that turkeys have a relatively high vitamin B requirement. Since this conclusion was based on the feeding of yeast, it is probable that the response was due to the riboflavin of the yeast.

Other reports[37] have indicated the riboflavin requirement for normal growth and hatchability to be between 270 and 350 micrograms per 100 grams of ration.

Pyridoxine. The California Station[38] reported pyridoxine deficiency in turkeys similar to that in chicks, being characterized by loss of appetite, poor growth, apathy, hyperexcitability when

disturbed, convulsions, and death. The requirement was indicated as 300 micrograms per 100 grams of ration.

Choline. Choline[39] has been shown to be necessary to prevent perosis. The requirement for poults has been indicated as being 800 to 1100 milligrams per pound. The requirement for turkey breeders is lower, 370 milligrams per pound being reported as sufficient for hatchability.

Folic Acid. A deficiency of folic acid[40] will result in slow growth, cervical paralysis, anemia, and high mortality. Several of the reports indicate the requirement for poults as being 80 micrograms per 100 grams of feed. Approximately half that amount seems to be sufficient for hens.

Niacin. A deficiency of niacin[41] will result in retarded growth, perosis, diarrhea, poor feathering, mouth inflammation, and high mortality. The deficiency symptoms were prevented by including 3 to 5 milligrams of niacin per 100 grams of ration. Higher levels may be needed for optimum growth, at least 5 milligrams probably being necessary. Niacin also helps in preventing the enlarged hock condition.

Pantothenic Acid. A ration deficient in pantothenic acid[42] will result in slow growth and dermatitis of the mouth. Approximately 10.5 milligrams per kilogram of diet are required for optimum growth.

Biotin. The Pennsylvania Station[43] concluded that biotin protected turkey poults from dermatitis.

Vitamin B_{12}. The vitamin B_{12} requirement for starting turkey poults has been reported as 5 to 10 micrograms per kilogram of ration.[44]

Other vitamins as yet unrecognized are also essential. This is true for at least one factor involved in the production of the enlarged hock disorder in turkeys.[45]

FIBER.[46] Turkeys can tolerate more fiber than can chickens. Good gains and good quality have been reported for growing turkeys with diets containing up to 20 per cent. However, feed efficiency was best with lower levels. Quality of plumage was improved and feather pulling retarded with the higher fiber rations. The level of fiber in the mash did not affect weight since the per cent of whole grain selected was related to mash fiber levels.

SUMMARY. As a summary of the information available to date, the nutrient requirements for turkeys are indicated by the Committee on Animal Nutrition of the National Research Council[47] (Table 30). The figures do not include margins of safety

TABLE 30. NUTRIENT REQUIREMENTS* OF TURKEYS

	Starting Poults, 0–8 weeks	Growing Turkeys 8–16 weeks	Breeding Turkeys
Total protein, %†	28	20	15
Vitamins			
Vitamin A activity (U.S.P. units)‡	2400	2400	2400
Vitamin D (I.C.U.)§	400	400	400
Riboflavin, mg.	1.7	?	1.5
Pantothenic acid, mg.	5.0	?	?
Choline, mg.	750	?	?
Folacin, mg.	0.4	?	?
Minerals			
Calcium, %‖	2.0	2.0	2.25
Phosphorus, %¶	1.0	1.0	0.75
Manganese, mg.	25.0	?	15.0
Salt, %**	0.5	0.5	0.5
Amino acids, %			
Arginine	1.6	—	—
Lysine	1.5	—	—
Methionine††	0.87	—	—
or			
Methionine	0.52	—	—
Cystine	0.35	—	—
Tryptophan	0.26	—	—
Glycine‡‡	1.0	—	—
Isoleucine	0.84	—	—

*In percentage or amount per pound of feed.

†The protein content of rations for growing turkeys from 16 weeks to market weight may be reduced to 16 per cent.

‡May be vitamin A or pro-vitamin A.

§International chick units.

‖This amount of calcium need not be incorporated in the mixed feed inasmuch as calcium supplements fed free choice are considered as part of the ration.

¶At least 0.50 per cent of the total feed of starting poults should be inorganic phosphorus. All the phosphorus of nonvegetable feed ingredients is considered to be inorganic. Approximately 30 per cent of the phosphorus of vegetable products is nonphytin phosphorus and may be considered as part of the inorganic phosphorus required. Presumably a portion of the requirement of growing and breeding turkeys must also be furnished in inorganic form.

**This figure represents added salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content.

††Cystine will replace methionine as long as the ration contains not less than 0.52 per cent methionine.

‡‡Glycine can be synthesized, but the synthesis does not proceed at a rate sufficient for maximum growth.

to compensate for possible losses of vitamins during processing, transportation and storage, and for variations in feed composition and in environment. In earlier reports the National Research Council suggested allowances which included margins of safety of 66 per cent for vitamin A, 50 per cent for vitamin D, and 20 per sent for the water-soluble vitamins.

MAKING UP A TURKEY RATION

Most of the common cereals have been used in turkey rations.[48-53] No appreciable differences in the rate of growth have been reported for corn, wheat, oats, barley, rye, milo or kafir, sorghums, and proso millet. However, oats showed a lower feed efficiency.

The Wyoming Station[54] reported on the influence of various feeds upon the quality of meat in turkeys. None of the grains had any significant effect on the dressing shrinkage, but the corn- and wheat-fed birds averaged a higher market grade. Oats and corn produced softer fats than barley or wheat, with rye intermediate. Oats produced a more intense and desirable aroma in the roasted bird. Corn, oats, and rye produced a texture of breast meat superior to the texture produced by wheat and barley. The corn-fed birds were slightly more tender when roasted and had the greatest amount of juice. Corn gluten meal produced a decidedly yellow-colored dressed turkey. Dry skimmilk produced a less intense aroma in the breast meat. Soybean oil meal and cottonseed meal produced a coarser texture in the breast meal after roasting The least desirable flavor was found in birds fed cottonseed meal. Corn gluten meal produced a better quality of juice than any of the other concentrates.

The Utah Station[55] reported that alfalfa meal could be fed in large quantities to growing turkeys and could be used up to 35 per cent of the mash when a good grade of alfalfa meal could be purchased at a lower cost per pound than ground wheat, barley, or millrun bran and shorts.

The California Station[56] indicated that raisins may be used as a cereal substitute in rations for growing turkeys, replacing 30 per cent of the grain portion or 16 per cent of the entire ration

The various vegetable protein concentrates[57] have been fed successfully to furnish protein in turkey rations, when such deficiencies as calcium, phosphorus, and lysine have been corrected. Soybean oil meal, corn gluten meal, and cottonseed meal have all been fed. Corn gluten meal has been reported as producing a superior fleshing condition.

TABLE 32A. GROWTH RATE AND FEED CONSUMPTION OF BELTSVILLE SMALL WHITE TURKEYS

Age in Months	Age in Weeks	Average Weight of Toms and Hens Combined lb.	Gain in Weight for Period, lb.	Feed Consumed Each Week (Mash and Grain), lb.	Total Cumulative Feed Required lb.	Successive Weekly Feed Required per Pound of Gain, lb.	Feed Required per Pound of Gain to Date, lb.
		0.11					
	1	0.22	0.11	0.17		1.5	1.5
	2	0.40	0.18	0.33	0.5	1.8	1.7
	3	0.60	0.2	0.5	1.0	2.5	2.0
	4	.90	0.3	0.8	1.8	2.7	2.3
1	Total	0.90	.79	1.8	1.8	2.3	2.3
	5	1.2	0.3	0.8	2.6	2.8	2.4
	6	1.6	0.4	1.1	3 7	2.8	2.5
	7	2.1	0.5	1.4	5.1	2.8	2.6
	8	2 6	0 5	1.4	6 5	2.8	2 6
2	Total	2.6	1.7	4 7	6.5	2.8	2.6
	9	3.2	0.6	1.6	8.1	2.8	2.6
	10	3.8	0.6	1 7	9.8	2.9	2.7
	11	4.5	0.7	2 1	11.9	3.0	2.7
	12	5.2	0.7	2.1	14 0	3 0	2.8
3	Total	5 2	2 6	7.5	14.0	2.9	2 8
	13	5.9	0.7	2.2	16.2	3.1	2.8
	14	6 6	0.7	2 4	18.6	3.4	2 9
	15	7 2	0 6	2 5	21.1	4.1	3 0
	16	7.8	0.6	2.7	23.8	4.5	3.1
4	Total	7.8	2 6	9 8	23.8	3.8	3 1
	17	8.4	0 6	3.0	26.3	5.0	3.2
	18	8.9	0 5	3.4	29 7	6.8	3.4
	19	9.3	0 4	3 8	33 5	9.5	3.7
	20	9 6	0.3	4 4	37.9	14.5	4.0
5	Total	9.6	1 8	14.6	37.9	8 1	4 0

(III) on woodland. The two free-running groups were later put on wheat stubble. The saving in food in both grassland and stubble was 40 per cent. The difference between the cultivated and woodland groups was of no importance.

The Michigan Station[51] reports that the inclusion of green feed, as alfalfa, lawn grass, or green oats in the ration, had little apparent influence on the rate of growth, feathering, or other features of development, but did result in a slight saving in the total feed cost in some instances. The Pennsylvania Station[70] obtained better weight and better market quality more rapidly with turkeys fed grass clippings artificially dried and

soaked in water overnight than those allowed only dry forage.

The Kansas Station[71] found that restricting the diet to grain and young grass range a few weeks before marketing reduced the size somewhat but materially lowered the cost of production.

Turkeys have been reared successfully in confinement. The Michigan Station[72] reported that rearing in confinement to maturity was slightly more efficient than rearing in yards. Control of mortality from diseases and predators gave satisfactory results in cobblestone yards over a 7-year period. The Oklahoma Station[73] reported no difference between birds grown in complete confinement and those grown on Bermuda grass range. Feed consumption in the confined groups is usually greater than in the range groups. Feather picking might occur in confined groups, which might reduce the market quality of some of the turkeys. The North Dakota Station[74] reported somewhat better growth for the turkeys on range than for those kept in cages.

FEEDING AND MANAGING THE BREEDERS. A good hatching egg is a fertile egg that contains in the correct amounts all the protein, carbohydrates, fat, minerals, and vitamins; in fact, all the ingredients (except oxygen) that are necessary for life and growth of the embryo during the 28-day incubation period.

Breeders in confinement cannot lay eggs that contain all the food ingredients required by the embryo, unless these ingredients are supplied in the breeder ration. Breeders that have been confined and wintered on grain alone cannot be expected to produce good hatchable eggs until after a more complete ration has been supplied or until the spring grass, sunshine, bugs, and the like have enabled them to balance the ration for themselves

The ration for growing poults may be continued through the winter and until about 30 to 60 days prior to the mating season, at which time a breeder ration should be substituted.

The Kansas Station[75] reported on restricting food intake during the nonlaying period, with free access to feed thereafter Neither the number of eggs laid nor their hatchability was influenced by reducing the intake to 78 per cent of that of the free-choice group. Reducing the intake to 61 per cent, however, significantly reduced hatching power.

Although the date at which the breeders start laying depends largely on the influence of artificial lights and housing conditions, feed also hastens or retards this laying period, besides influencing the production and hatchability of the eggs and the livability of the poults

A 12- to 14-hour day should be provided for the breeders by

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A 12- to 14-hour day should be provided for the breeders by

the use of morning, afternoon, or morning and afternoon lights, depending upon the convenience of the operator. The lights should be started about 30 days prior to the desired production date.

When the breeders have been kept on a growing ration the breeder ration should be started about 30 days prior to the start of lay. When they have been roughed through the winter on grain alone, the breeder ration should be started 30 days earlier.

All feed should be hopper fed, and the hoppers and fountains should be kept on the wire-covered platforms. The feed should be in open hoppers before the birds at all times. Should the breeders tend to consume more grain than mash, the grain hoppers may be kept closed part of the time and opened at regular periods.

FEEDING AND MANAGING THE POULTS. Feed and water should be put in small feeders and fountains and placed before the poults when they are 36 to 48 hours old, or as soon as they are placed in the brooder house. Early feeding lessens the danger of the poults' eating litter and eliminates the trouble of teaching the poults to eat, provided the brooder house is maintained at a comfortable temperature and is free from drafts around the feeders and fountains. Hammond[76] reported that poults starved for 3 or 4 days had to be taught individually to eat after feed was available and that poults may fail to learn to eat or drink in the presence of other poults that are eating and drinking. He concluded that lack of water is the primary cause of loose, slimy gizzard linings that accompany early nonspecific mortality in turkey poults. Chilson and Patrick[77] concluded that turkey poults should be supplied with feed and water as soon after hatching as possible since withholding feed and water for 24, 48, and 72 hours after hatching resulted in 4.8, 11.5, and 29.3 per cent mortality respectively up to 12 weeks of age.

FEEDERS AND FOUNTAINS. Many different types of good commercial feeders and fountains, also homemade ones, are in use on turkey farms. The amount of feeder and fountain space, rather than the kind of feeder, is the important factor to consider. Fifteen feet of feeder space to 150 poults will permit 30 to 50 per cent of them to eat at one time during the first 4-week period. Not more than 150 poults should be brooded in a 10- by 12-foot compartment or under one hover. However, lack of feeder and fountain space is as serious a brooding fault as crowded brooder houses.

FINISHING TURKEYS. The poults that have been properly

grown on a full and well-balanced ration will usually need little or no extra fattening to get them ready for the market. Turkeys that have been merely maintained during the growing season and then fattened rapidly just prior to the time of marketing lack the tenderness, juiciness, and excellent flavor of a rapidly grown bird. Turkeys that will not fatten or finish properly until practically full grown are the slow-maturing kind that should be eliminated from the flock by the proper selection of breeders.

The North Dakota Station[78] reported that broad-breasted turkeys marketed at 28 weeks of age after an 8-week finishing period were in satisfactory market condition. Use of a moist mash twice daily made considerable extra work not warranted by returns. Feeding of the grower mash with the whole grains fed separately produced the heavier males and females after 8 weeks of finishing and at the lowest feed cost per pound of gain.

Fish products affect the flavor. Bryant and Stevenson[79] reported that fishy flavor was detected in the roasted carcasses of turkeys receiving 10 per cent or more of fish meal. Fishy flavor was eliminated within 7 weeks after the 10 per cent level of fish meal feeding was discontinued and within 8 weeks after the 20 per cent level was discontinued. The drippings had a more pronounced fishy flavor than did the meat, and male birds exhibited a slightly stronger fishy flavor than females. The Pennsylvania Station[80] also reported fishy flavor and odor in the roasted carcasses of turkeys 28 weeks old, fed either 1 per cent of cod liver oil or 10 per cent of fish meal. The removal of both cod liver oil and fish meal from the diet 8 weeks prior to slaughtering time practically eliminated the occurrence of both fishy flavor and odor. The California Station[81] reported that high-grade fish meal, at a level of 25 per cent of the entire ration, did not apparently produce an off flavor when the birds were properly handled. When the birds were not starved before killing and were kept in a warm room overnight, the flavor was adversely affected, and, when so treated, birds fed inferior fish meals had a poorer flavor than birds fed a high-grade fish meal. Birds fed 2 to 5 per cent of fish oil showed an off flavor and odor when cooked. Marsden and coworkers[82] found that fishy off-flavors persisted 4 to 13 weeks after turkeys were removed from starting diets. They recommend that the feeding of fish meals and oils in turkey starting diets be restricted in quantities and that fish products be excluded from growing diets.

TURKEY RATIONS

It is possible to formulate many rations which will be satisfactory. Some of the representative turkey rations being recommended will be found in the Appendix. (See page 586.)

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CHAPTER 17

FEEDING WATERFOWL

FEEDING DUCKS

The rations for ducks are similar to rations for hens. This similarity applies particularly to the feeds that are used. However, ducks can make use of a larger amount of green feeds than hens, and fresh-cut greens can be fed if the flock does not get an abundance of green feed on range. It is not necessary to furnish water for swimming, but the ducks make better use of their feed and are more contented if water is available at feeding and until the feed is eaten up.

METHODS OF FEEDING. Duck mashes have usually been fed moist. In this case, sufficient water should be added to cause the materials to stick together, but the feed should never be so wet as to be sloppy. Since ducks seem to prefer a sticky mash, low-grade flour or similar feeds are frequently added to make the mixture more sticky.

In comparing methods of feeding ducks, the Indiana Station[1] produced satisfactory gains when an all-mash chick starting ration was fed ad libitum to ducklings as a dry mash. The same ration fed as a moist mash four times daily gave only a slight increase over the dry mash. When the ration was fed as a moist mash ad libitum, it apparently produced a significant increase in the rate of growth as compared to the other two methods of feeding.

Of five methods of feeding ducklings in the Philippines[2] it was observed that the best method was giving them uncooked mash and allowing them free access to all the green feed they would eat. Cooking the mash increased the amount of feed consumed. The addition of green food reduced the amount of feed consumed.

In recent years, the use of pellets has increased for duck feeding. This method simplifies the feeding very considerably since the pellets are fed in pans, troughs, or hoppers, and the birds are allowed to eat what they care to. The pellets are usually made available at all times, and fresh water is supplied continuously. The pellets are usually the same composition as the regular mash mixture. The results are practically the same

as with wet-mash feeding. In comparing pellets versus wet mash for table duck production, experiments conducted in England[3] showed in one case that slightly greater final weights were obtained from the mash-fed ducklings whereas in another trial the ducklings reared on pellets were heavier than those reared on mash.

At Cornell[4] feeding pellets to ducklings resulted in the highest average weight. Following the pellet-fed ducks in order were the ducklings getting dry mash ad libitum supplemented with 3 wet mash feedings daily, dry mash ad libitum, wet mash ad libitum, and wet mash fed four times daily.

FEEDS. The feeds commonly given to chickens are also given to ducks.

Animal feeds seem to be particularly adapted to the feeding of ducks. It has been reported[5] that even such forms of animal food as scales of fish, which are digested only with great difficulty by other animals, are digested by ducks in a very short space of time.

Horton[6] reported that a ration containing milk produced a market duckling of better quality than a ration without milk. In experiments reported from Germany[7] a combination of fish meal and soybean oil meal gave better results than sour skim-milk curd. Roberts[8] concluded that an all-mash ration containing 10 per cent of meat and bone scraps and 5 per cent of dried milk fed ad libitum as a dry mash proved satisfactory for growing ducks during the first 10 weeks. This combination was superior to 10 per cent of meat scraps with no milk. There seemed to be little to be gained by using more than 10 per cent of meat scraps in combination with 5 per cent of dried milk in this type of ration.

In rations for egg production, it was shown in experiments conducted in the Philippines[9] that 30 per cent of fish meal in the ration gave a better egg yield than either 20 per cent or 50 per cent. Mortality was excessive at the higher levels of fish meal, but the 20 per cent level was considered most economical. For growing ducklings 30 per cent of fish meal as the only protein supplement in the ration was found to be optimal. Weight increase, mortality, and feather development were adversely affected when higher or lower percentages were used. Experiments reported from England[10] showed no significant difference in the egg production of ducks receiving fish meal or meat and bone meal, but because the latter was lower in price it was more economical.

Weight for weight, fish meal was reported as being greatly superior to shrimp meal as a protein supplement for laying ducks.[11] The rations containing 40 per cent shrimp meal proved slightly superior to those containing 30 per cent fish meal only as to percentage of egg production, but such rations were too expensive owing to the higher price of the shrimp meal.

Substitution of copra meal[12] for fish meal in standard rations for laying ducks proved detrimental to egg production. The health of the birds did not suffer, but there was a decreased food consumption when the copra meal was fed. Soybean meal has been shown to be a satisfactory source of protein for ducks.[13]

Egg production was maintained at a fairly high level in groups of ducks receiving a ration in which 50 per cent of the dry matter was provided by town food waste, or by equivalent parts of town food waste and steamed potatoes.[14] Difficulty was experienced with higher levels of substitution because of the very bulky nature of the rations.

At Cornell[15] potato meal was substituted for corn meal and wheat standard middlings or a combination of these feeds. Thirty per cent of potato meal was the maximum amount that could be fed.

GROWTH AND FOOD CONSUMPTION. Ducklings make very rapid gains early in life. Green ducks or fancy ducklings can be fed so that they will weigh about 6 pounds in 8 to 9 weeks.

The growth rates and feed consumption for White Pekin ducklings given in Table 33 were obtained by Heuser and associates.[15]

The average rate of growth and weekly consumption of feed

TABLE 33. GROWTH RATE AND FEED CONSUMPTION OF WHITE PEKIN DUCKLINGS

Week	Average Weight Per Duckling, lbs.	Cumulative Feed Consumption Per Duckling, lbs.	Amount of Feed to Produce 1 Pound of Duck, lbs.
When hatched	.133	—	—
1	.334	.28	.84
2	1.01	1.17	1.16
3	1.61	3.17	1.93
4	2.53	5.72	2.26
5	3.32	8.51	2.57
6	4.42	11.75	2.66
7	5.31	14.96	2.82
8	6.08	18.69	3.07
9	6.62	23.06	3.48

per duckling of different breeds of ducks up to 12 weeks of age have been reported by Elford[16] as follows:

Breed	Average Weight, lb.	Feed Consumed, lb.
Pekins	7.09	28.03
Rouens	5.98	28.00
White Muscovies	5.09	21.97
Colored Muscovies	5.73	21.91
Indian Runners	4.07	29.40
Khaki Campbells	4.13	23.46

FEEDING DUCKLINGS

REQUIREMENTS. Relatively few experimental results are available dealing with the nutritive requirements of ducks.

Protein. Horton[17] reported that a well-balanced 19 per cent protein chick mash to which approximately 10 per cent of flour was added was satisfactory for growing White Pekin ducklings. He further stated that they could be grown successfully on a low-protein mash but that the total feed consumption was greater and the cost of feed was higher. Hamlyn, Branion, and Cavers[18] reported that a total protein level of about 25 per cent is approaching an excess of this nutrient in a ration for growing ducks and the optimum protein level would seem to be about 18 per cent or less. In comparing a 17 per cent ration with one containing 14 per cent of protein, Miller[13] showed slight differences in weight during the growing period between the high- and low-protein groups. Scott and Heuser[19] produced satisfactory gains in ducklings to 8 weeks of age on a ration containing approximately 15 per cent of protein. However, there was some indication of a slight advantage in early growth for rations containing 17 per cent or more of protein.

Demers and Bernard[20] concluded that in the presence of 0.4 per cent cystine, approximately 0.5 per cent methionine is required for normal growth.

Vitamins. Reporting on the vitamin D requirements of ducklings, Fritz, Archer, and Barker[21] concluded that the vitamin D requirements of White Pekin ducklings are approximately the same as those of chicks and that 30 A.O.A.C. (22.5 International) chick units of vitamin D per 100 grams of feed will produce optimum calcification. Motzok and associates[22] conclude that the vitamin D requirement of ducklings appears to be between 30 and 40 A.O.A.C. (22.5 and 30 International) chick units per 100

grams of ration. Olsson[23] places the requirement at 80 A.O.A.C. (60 International) chick units per 100 grams of feed.

Hegsted[24] reported the symptoms of niacin deficiency as lack of growth, diarrhea, and general weakness, indicating a requirement of 2.5 milligrams of niacin per 100 grams of ration. Results at Cornell[25] showed that a bowed leg disorder in ducklings was entirely prevented by supplementing the diet with 5 to 7.5 per cent of dried brewers' yeast or by adding 10 milligrams of synthetic niacin per pound of ration. Satisfactory growth was obtained with the addition of 3.8 per cent of dried brewers' yeast or 5 milligrams of synthetic niacin per pound of ration.

Other water soluble[26] vitamins are also necessary. The riboflavin requirement of ducklings has been reported as being 300 to 400 micrograms per 100 grams of diet, the pantothenic acid requirement as 1100 micrograms per 100 grams of diet, and the pyridoxine requirement as 250 micrograms per 100 grams of ration. Neither riboflavin nor pantothenic acid deficiencies produce characteristic symptoms. Pyridoxine deficiency is characterized by growth failure and anemia in young ducklings and also convulsions and paralysis in older ducklings. Biotin is required by the duck, but the only effect of a deficiency is very poor growth.

Scott and Heuser[19] concluded that dried skimmilk and dried brewers' yeast contain some unidentified factor or factors of importance in the nutrition of ducklings.

Minerals. Bernard and Demers[27] concluded that 15 parts per million of manganese in the ration was sufficient to prevent perosis in ducklings but that it required 60 parts per million to bring the alkaline phosphatase activity of blood serum near normal values. Van Reen and Pearson[28] indicate the magnesium requirement as being 50 milligrams per 100 grams of diet.

Fiber. Serfontein[29] reported that for ducklings a ration which was low in fiber produced the highest average weight at 10 weeks. Although growth after the age of 4 weeks was apparently not much affected by the high percentage of fiber, it appeared to be best to feed a ration low in fiber throughout the growing period.

As a summary of available information the Committee on Animal Nutrition of the National Research Council[28a] recommends the tabulated nutrient requirements for ducks on the next page.

Feeding Management. Ducklings are usually fed within 36 hours after the hatch is completed or as soon as they are placed in the brooder house.

If crumbly wet mash is fed, it is given four or five times a

NUTRIENT REQUIREMENTS* OF DUCKS

	Starting and Growing Ducks
Total protein, %	17
Vitamins	
Vitamin D (I.C.U.)†	100
Riboflavin, mg.	1.8
Pantothenic acid, mg.	5.0
Niacin, mg.	25.0
Pyridoxine hydrochloride, mg.	1.2

*In percentage or amount per pound of feed.
†International chick unit.

day during the first week or two. Later the number of feedings is reduced to three or four.

Fresh drinking water should be provided at each feeding period. The fountains should be arranged so that the ducklings can submerge their bills in the water but cannot get into it to wet their bodies. This permits them to drink and also allows them to clean their nostrils by squirting water through them. Any wet mash left over after the ducklings have had their fill should be removed. Sand or grit should be kept before them at all times.

If pellets are fed they are kept before the ducklings all the time, with a plentiful water supply available.

Chopped fresh green feed or cooked vegetables are often used in the ration for ducklings, as well as for older ducks. No grain is fed to ducks grown for market. In developing ducks for egg production, grain is sometimes fed at night after they are 4 months old.

Enough feeding space should be provided for the ducks to eat without crowding. Ducks should be fed only what they will clean up in 20 minutes, when the wet mash system of feeding is used.

FATTENING. When fattening or finishing of the ducklings is carried on it is usually done 2 to 3 weeks before marketing. A heavy daily feed consumption is necessary during the fattening period. During this period it is best to give a light noon feeding and then a heavy feeding at night. Fattening ducks require less range than growing ducks, and it is advisable to have the source of drinking water near the feed trays for heavy ducks.

FEEDING AND MANAGEMENT OF YOUNG BREEDERS. From the time ducklings are selected as breeders, at about 8 weeks of age, until the breeding season begins, every effort should be

made to develop and condition them for egg production. Both drakes and ducks should be fed pellets or given a good growing mash, mixed grain, and green foods. It is highly desirable to run them on pasture if it is available. About equal parts of mash and grain may be fed. They should complete their growth after they molt and reach the laying stage in good-bodied flesh. About a month or 6 weeks before eggs for hatching are desired, a breeding ration should be substituted for the growing ration. The same method should be followed with the laying type of ducks, such as the Indian Runner.

FEEDING THE MATURE DUCKS. The rations for laying ducks are similar to rations for hens. The breeders should have a breeder ration. If pellets are not fed, the mash part of the ration is moistened and the ducks are given all the wet mash they will eat morning and night. This wet mash should be neither too crumbly nor too wet but of such a consistency that it will hold together when squeezed with the hand or, if dropped, will fall apart in lumps. A mixture of grain is usually fed in addition to wet mash. In England it is customary to feed laying ducks a hard grain in the water trough. About two parts of mash are fed to one part of grain. Oystershell or high-grade limestone grit should be supplied to provide calcium for eggshell formation. In addition, granite grit or gravel should be available in each pen.

Feed is usually given twice a day, with a light feeding in the morning (10 minutes) and a heavy feeding at night (20 minutes). The drinking water should be near the troughs. The average daily feed consumption for about 200 ducks is 100 pounds of feed, of which 40 pounds should be fed in the morning and 60 pounds at night.

Considerable attention has been given to the breeding and management of ducks in England. At the Harper Adams College laying trials an average egg production of about 250 eggs per duck has been obtained. The feeding method employed was as follows.[30] The first feed is given when the ducks are being released from the trapnest. It consists of 1 ounce of grain per duck, given in the water trough. The second feed, given at 11 A.M., is wet mash, the quantity allowed being rather less than one-half of the total daily mash ration. The third feed, given in the afternoon, is the rest of the mash and also 1 ounce of grain placed in the water trough as in the morning. Each duck therefore receives about 2 ounces of grain and 4 ounces of mash daily.

RATIONS FOR DUCKS. Some rations that have been recommended for ducks will be found in the Appendix. (See page 609.)

FEEDING GEESE

Geese are generally reared where they have a good grass range or pasture as they are good grazers and, except during the winter months, usually pick up most of their living. They are not adapted to intensive conditions.

FEEDING THE ADULT GEESE. The pasture may be supplemented with light feedings of home-grown grains or wet mash daily, the necessity and quantity of this feed depending on the condition of the pasture.

During the winter, when pasture is not available, geese should have both grain and roughage, but great care should be taken not to overfeed the breeders so that they will become fat. Oats make a desirable grain feed for breeding geese, but a limited portion of corn, wheat, or barley may be added for variety. The greater part of the feed should be made up of roughage such as vegetables, clover or alfalfa hay, chopped corn stover, or silage.

As the breeding season approaches, it is necessary to increase the quantity of feed and add to it a mash which is usually given in the morning. A good duck breeder or hen breeder mash can be fed. A simple mixture which has given satisfactory results is made up of 3 parts of wheat by-products, 1 part of corn meal, and 1 part of meat scrap. Buttermilk may be used in place of the meat scrap.

Grit and oystershells should be kept before the geese when they are laying and may be provided all the time to advantage. Drinking water, which should be available at all times, is best supplied in drinking fountains or vessels so constructed that the stock cannot get their feet into the water.

FEEDING THE GOSLINGS. Goslings do not need feed until they are 36 to 48 hours old, when they can be fed a chick or duckling ration. This can be fed as pellets or in the form of wet mash, or they can be fed stale bread soaked in milk or water, scalded cracked corn, or a mash made of 4 parts corn meal and 1 part middlings. Green grass should make up most of their feed, and only a very limited amount of grain should be used. Plenty of fresh clean drinking water should be supplied. After 2 or 3 weeks, if the goslings have plenty of grass, they will usually not need much other feed until fattening time.

If the goslings are confined the ration should include vitamin

D. Olsson[23, 31] indicates the requirement for goslings as 30 to 35 chick units per 100 grams of feed. Choline, folic acid, and nicotinic acid have been shown necessary for goslings fed purified diets.[32] Folic acid deficient geese showed cervical paralysis.

Experiments reported from England[33] showed that little advantage was gained by feeding concentrates to goslings throughout the growing period, provided they have free access to good grazing. The final weights of birds at 34 weeks of age that had received mash throughout the experimental period were only slightly greater than the average weights of those birds that had no supplementary feeding from the age of 5 weeks to 26 weeks and from 5 weeks to 30 weeks. All the birds were in good marketable condition at the end of the experiment. It was concluded that a satisfactory carcass could be produced without the use of concentrates from the age of 5 weeks until a month before marketing. On the other hand, it was reported[34] that confining the goslings and providing cut grass as a sole food was insufficient to promote a normal growth rate.

Geese can consume relatively larger quantities of potatoes than hens. It has been reported[35] that goslings, 2 to 3 months old, could eat 300 to 400 grams of potatoes per day. Potatoes can also be fed to adult geese, but care must be taken that they do not become too fat during the laying period.

PREPARING FOR MARKET. In the final fattening or finishing period grain is usually fed. Corn is commonly fed to geese for fattening. Sometimes corn on the cob is fed. The geese may be fattened on range or in pens.

One recommended method for pen fattening is to feed 3 times daily, 1 feed of a moist but not sloppy mash made up of 1/3 shorts and 2/3 corn meal and 2 feeds of corn with some oats or barley. Some roughage or vegetables should be provided.

Such feeds as dried sugar beets, molasses, and skimmilk have been used satisfactorily in fattening geese in Germany.[34]

Noodling Geese. The following method for noodling geese is described by Lee.[36] This method, which produces a much better-fattened goose than ordinary procedures but involves considerably more work, is to stuff large geese with noodles for 3 or 4 weeks. The feeders stuff the birds with noodles, usually beginning by feeding 3 to 5 noodles three times daily and gradually increasing to 6 or 7 noodles five times daily at 4-hour intervals. The noodles are made of scalded corn meal, ground oats, ground barley, and ground wheat or wheat flour, about equal parts of each being used. Add salt as for bread, thoroughly mix the feed,

and put it through a sausage stuffer, cutting the product into pieces 2½ or 3 inches long. Boil them 10 to 15 minutes, or until they float, in a wash boiler containing a wire rack which stands 1½ inches above the bottom of the boiler. Dip the noodles in cold water and roll in flour to keep them from sticking together. Pour hot water over the noodles, just before they are fed, to make them slippery and keep them warm. The number of noodles fed depends on the size and condition of the bird and the judgment of the feeder. The noodles are put into the mouth, one at a time, and worked down by using the hands on the outside of the neck. At the next feeding time, if any feed can be felt in the crop, no noodles are given; otherwise the bird will go off its feed. Keep plenty of drinking water before the geese. This method of feeding involves a large amount of work and long hours but will produce a gain of 6 to 10 pounds. One effect of noodling is the production of enormous livers that in Europe have been used for making pate de foie gras.

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CHAPTER 18

FEEDING OTHER SPECIES OF BIRDS

GAME BIRDS

In general, game birds grow more rapidly than chickens. For that reason their requirements for many of the nutrients are higher. They have, therefore, made better growth response to rations containing higher amounts of protein, riboflavin, and vitamin D.

Formerly a large variety of rations, most of which were very complex, were fed game birds. In most cases, the rations also included special feeds or ingredients. Many game breeders considered it impossible to grow a bird except by using worms and other natural feeds, such as artificially produced larvae.

In recent years rations similar to those developed for the feeding of chickens and turkeys have also been fed game birds. There have also been made available by commercial feed companies feed mixtures designed particularly for certain species of game birds such as pheasants and quail.

In comparing the value of grains[1] for winter game feeding, it has been found that pheasants, quail, and partridge like yellow corn better than any other feed. Next in the order of consumption preference are wheat, scratch feed, and buckwheat, followed by white corn, popcorn, barley, sweet corn, and sudan grass seed. The smallest amounts consumed were sorghum seed, soybeans, oats, and rye.

PHEASANTS

It has been shown that it is possible to rear pheasants without resorting to complex rations or complicated systems of feeding. In fact, rations and methods similar to those for the rearing of chickens and turkeys have proved satisfactory. The pheasant chick resembles the chick in its response to energy and the animal protein factor.[2] It is necessary, of course, to adapt the ration to meet the particular nutritive requirements of the pheasant.

Requirements. The pheasant is a rapidly growing animal. It has been known to increase from a hatching weight of approximately 19 grams to an average weight of about 450 grams at 8

weeks of age, and nearly 700 grams at 12 weeks of age. Callenbach, Murphy, and Hiller[3] showed that better growth was obtained on a high-protein ration than on a lower-protein ration suitable for chicks of the domestic fowl. Later Callenbach and Hiller[4] reported best growth and feathering on a 28 per cent protein ration. Norris, Elmore, and Bump[5] obtainted maximum growth in ring-necked pheasant chicks during the first eight weeks of life by feeding a ration containing 30 per cent protein. Excellent growth, however, was also obtained on rations containing 21 per cent, 24 per cent, and 27 per cent protein. They concluded that, in practice, satisfactory growth without undue forcing will be obtained by feeding a ration containing 24 per cent protein. Skoglund[6] reported improved results for starting ring-necked pheasants by substituting soybean oil meal for part of the meat scrap and fish meal. Besides slower growth on low-protein rations, cannibalism and feather pulling have also been reported to be more prevalent in low-protein lots.

The pheasants also have a relatively high riboflavin requirement. Norris[7] concluded that the riboflavin requirement of pheasants during early growth was satisfied when approximately 4 per cent of dried pork liver was included in the ration, approximately twice the amount necessary for chicks. In a practical pheasant-rearing ration, approximately 20 per cent of dried skimmilk, or its equivalent in other riboflavin carriers, will be required to meet the requirements of pheasant chicks for this vitamin.

Baird and Greene[8] concluded that pheasants require a minimum of approximately 50 to 60 U.S.P. units of vitamin D per 100 grams of feed. This is approximately three times the quantity necessary to prevent the development of rickets in chicks.

The calcium requirement has been reported to be 1.5 per cent and the phosphorus requirement 0.75 per cent.[6] When meat scrap and fish meal are fed to supply the necessary high level of protein, perosis is frequently encountered because of the high calcium and phosphorus content of these ingredients. However, with a ration containing 35 parts per million of manganese no particular difficulty was experienced when the calcium was kept under 2.84 per cent and the phosphorus under 1.08 per cent.

Growth and Feed. Callenbach and Hiller[4] reported that it required 3.44 pounds of feed per bird up to 8 weeks of age and 6.77 pounds up to 12 weeks of age. Skoglund[6] indicates a requirement of 3.55 pounds per pheasant to 8 weeks of age.

Methods of Feeding. For the feeding of young pheasants, the

all-mash method has proved satisfactory. The mash is kept constantly available in hoppers. Some feeders prefer to give moist mash to young pheasants. In some cases, commercial chick grain is also introduced after the birds are 3 to 4 weeks old. Callenbach and Hiller[4] reported that the free-choice or cafeteria system of feeding did not give satisfactory results. Pellets have also been fed.

Grit can be fed on top of the feed for the first few weeks, after which time it can be made available in hoppers. Fresh drinking water should also be given each day.

Mature birds are fed rations similar to those fed breeding hens, which usually consists of a grain mixture and a mash mixture. The mash might be fed as a dry mash or a wet mash in the morning. The grain is fed in the afternoon. Usually all the grain that the birds will clean up before dark is fed. Mash feeding is begun at least 3 weeks before the birds are likely to lay in order to get the body in condition for production. Mash feeding can be discontinued when eggs are no longer needed for hatching. The birds should also have access to medium-sized grit and oystershell and fresh water.

Rations. Some ready-mixed rations are available for pheasants which are compounded to meet the specific nutritive requirements of this species. Satisfactory results have also been reported in growing pheasants by using turkey-growing rations or by feeding chick starters supplemented with milk.

The following rations have also been reported as giving satisfactory growth.

Cornell.[2]

	Pounds
Yellow corn meal	21
Wheat standard middlings	14
Pulverized oats	10
Soybean oil meal	30
Fish meal	5
Meat scrap	5
Dried skimmilk	5
Dried brewers' yeast	4
Dried whey	2
Dicalcium phosphate	1
Ground limestone	1.5
Fish liver oil (2000 A, 400 D)	1.0
Salt	0.5
Manganese sulfate	0.025

Pennsylvania. (The Pennsylvania State College Department of Poultry Husbandry, State College, Pennsylvania, Stencil G 134, 1951.)

STARTING MASH FORMULAS FOR RING-NECKED PHEASANTS

	No. 1	No. 2
Ground yellow corn	100	170
Wheat flour middlings	100	100
Wheat bran	100	100
Ground oats	100	100
Alfalfa meal, low fiber	50	50
Dried whey	50	50
Brewers' dried yeast (1)	30	30
Meat scrap (not less than 50% protein)	30	120
Fish meal (not less than 55% protein)	20	30
Soybean oil meal	400	250
Steamed bonemeal	10	—
Ground limestone	10	—
Salt	5	5
Fish liver oil (400 A.O.A.C. units of D per gram) (2)	2.5	2.5
Anhydrous manganese sulfate (3)	.125	.125
	1007.625	1007.625

1. If necessary, a riboflavin concentrate composed of natural ingredients may be substituted for the brewers' yeast. A pound for pound substitution may be made if the riboflavin concentrate contains 35 micrograms of riboflavin per gram of concentrate Adjustments can be made for concentrates of greater potency. If, for example, a product containing 70 micrograms per gram is used, 15 pounds in place of 30 pounds should be added and the ground yellow corn increased 15 pounds in the mash mixtures.

2. If desired, 0.5 pound of D-activated animal sterol, containing 2000 A.O A.C. chick units of vitamin D per gram may be substituted for the fish liver oil provided good quality alfalfa meal is used.

If oil is used, it should be premixed with 50 pounds of the bran before adding to the other ingredients

If D-activated animal sterol is used, it should be premixed with 50 pounds of the soybean oil meal before adding to the other ingredients.

3. The anhydrous manganese sulfate should be premixed with the ground limestone or salt before adding to the other ingredients.

GRAIN MIXTURE

200 lb	coarse cracked yellow corn
100 lb.	whole wheat
50 lb	whole oats
350 lb.	

Barley or buckwheat may be substituted for one-half the corn with satisfactory results

FEEDING DIRECTIONS

Pheasant chicks should be placed in brooding quarters and fed as soon as they complete their "after-hatching" sleep. Such quarters should be amply provided with filled chick-size mash hoppers and water receptacles. For 1 or 2 days some mash should also be sprinkled on egg flats, small pieces of newspaper, or cardboard. Each feeding of mash should be lightly covered with a small amount of insoluble grit until such time as the chicks are able to feed from a regular grit and shell hopper. The grit is shiny and seems to attract the attention of the tiny chicks. This helps teach them to eat, as does a small amount of finely chopped green feed sprinkled on top of the mash. When the chicks eat mash readily, the green feed may be discontinued.

After the chicks are 6 to 8 weeks of age, oystershells (or a high calcium limestone grit) and insoluble grit should be constantly available in hoppers. At this time, scratch grain may also be fed although this practice may be delayed until the chicks are twelve weeks of age. The simplest way to feed the grain is to keep it constantly before the birds in hoppers. A lower protein mash, similar to the Pennsylvania State chick mash, may be used after the twelfth week.

Until 5 weeks of age, Ring-necked pheasants may be kept very closely confined with excellent results. Thereafter, if the chicks are confined too closely much difficulty will be experienced from feather picking and mortality from cannibalism may be near. A good grass pasture, such as provided by clover and timothy, alfalfa, or some other vegetation that furnishes shade and cover, will be most helpful in supplying food and shelter after the birds are 5 weeks of age.

QUAIL

In recent years quail have also been successfully reared by methods similar to those applied to chicks. Feed ingredients are similar, but the amounts are adjusted to meet the nutritive requirements of the species. The information available concerning the nutritive requirements of the quail is somewhat limited.

Requirements. Norris[9] showed that the bobwhite required 27 per cent of protein in a diet for rapid growth. However, the difference between the results at the 24 per cent and the 27 per cent level was not great. Baldini, Roberts, and Kirkpatrick[10] reported a ration containing 28 per cent protein supplied by soybean oil meal as being adequate. Later they reported the lysine requirement as being higher for the quail than for the chick and concluded that 20 per cent protein was sufficient if the lysine of the ration was increased. Bass[11] concluded that 40 to 100 parts per million of manganese in a diet for bobwhites will prevent perosis.

Nestler and Llewellyn[12] reported an abnormal juvenile feather

growth in which primary and secondary wing feathers were curved, twisted, stunted, and, in many cases, frizzled, among pen-reared bobwhites. It was most prevalent on the diet containing no dried milk products. The incidence diminished as the percentage of milk products in the diet was increased but appeared in a few birds, even on the diet containing 15 per cent of dried buttermilk and 3 per cent of dried whey. They concluded that a deficiency of riboflavin apparently was the major but not the sole cause of the abnormality.

In experiments dealing with pen-reared bobwhites, Nestler and Llewellyn[12] balanced the ration so as to contain approximately 28 per cent crude protein, 1.1 per cent calcium, 0.7 per cent phosphorus, 2400 International units of vitamin A, 530 International units of thiamin, and 540 International units of vitamin D.

Feeding Management. Nestler and Bailey[13] suggest the following feeding and management for the propagation of bobwhites. All-mash diets are fed exclusively, and they are kept constantly before the birds. A supply of clean fresh water should always be available. The birds should also have access to insoluble grit. Green leaves are good sources of certain of the dietary factors but are not essential from the nutritive standpoint when the vitamins are furnished in sufficient amounts in the feed. However, fresh-cut greens can be fed to add relish to the diet.

For the mature birds the breeding diet is made available 1 month before the breeding season and continued as long as eggs are to be used for hatching purposes.

The growing diet is kept constantly before the birds for the first 12 weeks of their lives. After 6 weeks of age, the maintenance ration is also fed in separate hoppers and the birds allowed to eat what they wish of either of these diets.

The maintenance diet is fed alone, after the bird is 12 weeks of age, and continued until it is changed to the breeding diet.

Rations.

Breeding Diet (26% protein)

Ground yellow corn	25
Wheat standard middlings	10
Dehydrated alfalfa meal	10
Soybean oil meal	36
Dried buttermilk	12
Bonemeal	3
Limestone	2 1/2
Salt mixture	1
Feeding oil (400A, 3000D)	1/2

Growing Ration (28% protein)

Ground yellow corn	24
Ground millet	10
Dehydrated alfalfa meal	5
Soybean oil meal	42
Dried buttermilk	16
Bonemeal	0.9
Salt mixture	1
Vitamin A-D oil	0.3

Maintenance Diet (12% protein)

Ground yellow corn	85.6
Dehydrated alfalfa meal	5
Soybean oil meal	7
Bonemeal	1.2
Salt mixture	1
Vitamin A-D oil	0.2

The salt mixture used in the above rations is made up as follows:

Common salt	50.000
Anhydrous manganous sulfate	0.850
Anhydrous ferrous sulfate	0.550
Anhydrous copper sulfate	0.020

If iodine is needed, the following is also added:

Potassium iodide	0.035
Anhydrous sodium thiosulfate	0.032
Calcium carbonate	0.035

It will require about 2½ pounds of feed to rear the quail to 10 weeks of age.

Coburn and Nestler[14] reported that of 9 cereals used as the sole grain millet gave the best results. Any of the cereals could replace half the corn; millet, wheat, and rye were the leading three.

The Pennsylvania[15] station obtained the best results with the following mash mixture in experiments evaluating 15 mash mixtures.

	Pounds
Ground yellow corn	9.5
Wheat bran	10.0
Wheat flour middlings	10.0
Ground oats	10.0
Alfalfa leaf meal	5.0
Dried whey	5.0
Soybean oil meal	40.0
Fish meal	2.0
Meat scraps	3.0
Dried brewers' yeast	3.0
Ground limestone	1.0
Steamed bonemeal	1.0

PIGEONS

Pigeons are primarily grain eaters. The feeding of pigeons, therefore, differs from the feeding of other poultry in that they are not fed any mash or green feed but are given a ration of whole grains, a mineral mixture, and water. Usually some high-protein grains such as cow peas, field peas, or peanuts are included in order to increase the protein content in the ration since the ordinary scratch mixture used for chickens is usually low in protein.

Grains. The most important part of the pigeon diet is a mixture of dry, hard grains that are clean, of good quality, and free from mold and decay. Levi[16] gives the basic feeds as being corn, wheat, kafir, and peas in the proportion of one part of peas to four parts of the other grains.

Corn is one of the best feeds for pigeons. Yellow corn is a good source of vitamin A. Soft corn should not be fed, and whole corn is better than cracked corn. Kafir and milo are also good feeds. Corn and kafir together usually constitute the major part of the pigeon ration.

Field or Canada peas are most commonly used as the high-protein feed. However, other feeds such as cow peas, peanuts, soybeans, or vetch are also fed.

Wheat is also included in fairly large quantities in most pigeon rations. The hard red wheat is preferred to the softer varieties.

Other grains may also be fed, but they are usually included only in small quantities. Such grains are oats, hempseed, millet, buckwheat, rice, rape, and rye.

Hemp is very palatable and is sometimes fed to stimulate feed intake. Sunflowerseeds are not palatable and must be restricted.

Mineral Mixtures. A suitable mineral mixture is necessary for the pigeons since the grains and seeds are usually low in minerals. The mineral mixture usually supplies a grit for grinding and material which will furnish calcium, phosphorus, iron, and salt. Platt[17] reported that a combination of 85 per cent oystershell, 10 per cent charcoal, and 5 per cent salt appeared to meet the needs for squab production.

Water. A plentiful supply of clean, fresh drinking water should be provided. Some arrangement, however, should be made to prevent the pigeons from bathing in the water supply.

Green Feed. Green feed is not necessary, especially when

the birds get outdoors. Some feeders like to supply some green feed as a relish to pigeons when they are confined.

METHODS OF FEEDING. The usual method is to feed the grain by hand, two or three times daily. A common practice is to feed the grain in the morning and afternoon, giving as much as will be cleaned up in $1\frac{1}{2}$ to 2 hours. The grain is fed either *on the floor or in open troughs. Feeding in troughs is preferred* since it is more sanitary.

The grain may also be fed to the pigeons by making it available at all times in self-feeding hoppers. If the pigeons show a preference for certain of the grains, it might be advisable to put only about 1 day's supply of grain in the hopper at one time.

The quantity of feed that a given number of pigeons will eat depends on the weather, on their appetite, the breed, and on the number of squabs in the nest. One hundred pairs of Kings, or breeds of that size, will eat an average of about 27 pounds of grain each day.

Platt and Dare[18] reported very unsatisfactory results when attempting to feed an all-mash ration consisting of regular grain *mixtures ground in mash form. However, the feeding of* pellets has been done satisfactorily.

REQUIREMENTS OF THE RATION. Lee and Haynes[19] state that a good pigeon feed usually contains 13 to 15 per cent protein, 60 to 70 per cent carbohydrates, 2 to 5 per cent fat, and not more than 5 per cent fiber.

Supplementation of the ration with riboflavin and vitamin B_{12} has been reported as increasing the squab number owing to increased hatchability.[20] Livability was also increased with added riboflavin.

RATIONS. *The following rations have been used with good* results.

Cornell.[21]

	Per Cent
Cracked corn	30
Red wheat	20
Kafir corn	20
Canada peas	25
Rice, barley, or oats	5

U. S. Department of Agriculture.[19]

	Per Cent
Whole yellow corn	35
Kafir or milo	20
Cow peas	20
Hard red wheat	15
Oat groats	5
Hempseed	5

New Jersey.[22]

700 pounds whole yellow corn
400 pounds wheat
500 pounds milo
400 pounds green peas

Feed grain twice daily, giving the birds all they will eat. In addition, see that a regular pigeon grit and drinking water are available at all times.

New Jersey State Pigeon Breeding Test at Mellville.[23] From January to September, the birds were fed the following mixture:

	Pounds
Whole yellow corn	270
Cracked yellow corn	270
Wheat	260
Green peas	200

After October first, the mixture was changed to the following:

	Pounds
Whole yellow corn	300
Cracked yellow corn	150
Kafir corn	150
Wheat	200
Green peas	200

Many breeders of homing pigeons believe that a special feed is of value to induce the birds to enter the lofts promptly upon returning home after a flight. A mixture of this type, as well as a simpler combination, are recommended by Platt and Dare,[24] on the next page.

Some pigeon feeders change the ration during the summer. The chief change is to decrease the amount of corn. For example Levi[25] suggests the following:

Grains	Winter	Summer
Corn	35–56	20–40
Wheat	10–30	15–30
Kafir	9–18	15–35
Peas	18–20	20–25
Other	0–5	0–5

NEW JERSEY RATION FOR HOMING PIGEONS[24]

	Mixture 1	Mixture 2
Whole yellow corn (domestic)	30	..
Red wheat	20	15
Alaskan green peas	20	..
Kafir corn	15	25
Cracked yellow corn (domestic)	15	..
Argentine corn	..	30
Canada field peas	..	17
Maple peas	..	10
Hemp	..	2
Millet	..	2
Rice	..	2
Buckwheat	..	2
Hulled oats	..	3
Vetch	..	2
	100	100

FEEDING THE SQUABS. Squabs are reared and fed by both the parent birds on a thick, creamy mixture called pigeon milk, produced in the crop of the pigeons. The pigeons usually feed their squabs shortly after they themselves are fed and should not be disturbed at that time. If the parent birds become sick or die, the young birds may be fed by hand after they are a week old by dropping some of the smaller grain into the squab's mouth. They should be fed two or three times a day on grain that has been soaked for about 8 hours.

Squabs are usually ready for the market at about 28 days of age. Shortly after that time the squabs will leave the nest and feed for themselves, and then they will no longer have the quality of meat desired in the squab market. Squabs being saved for breeders can be removed from their parents at about the sixth week.

ECONOMICS OF FEEDING. Squabs will reach the weight of 14 ounces in about 25 days or about 1 pound in 4 weeks. There is some variation among the various breeds of pigeons in regard to the annual production of squabs, size of squabs, and feed consumption. The following averages were reported for ten different breeds at the New Jersey State Pigeon Breeding Test for a 5-year period:[18]

Squabs per pair annually	11.4
Grain per pair annually (lb.)	101.0
Grit per pair annually (lb.)	5.9
Grain to produce 1 lb. of squab dressed weight (lb.)	8.6
Weight per squab dressed (oz.)	16.3

CANARIES

The food requirements of canaries are very simple if the birds are not to be bred and young canaries reared. The chief requisite is a supply of canary seed to which may be added a small quantity of rape seed and a little hemp. Cuttle bone and water should always be available to the canary. In addition to the grain, occasionally such supplements as lettuce, chick weed, or a bit of apple may be fed. Bread that has been moistened in scalded milk or other soft foods may also be fed occasionally.

During the breeding season, the canary seed should be supplemented with egg food. It should be given daily from the first day the birds are placed in the breeding cage. Commercial nestling foods are also available which may be used in place of the home-mixed egg food.

The egg food can be made as follows: Mashed or riced hard-boiled eggs are mixed with fine crumbs, made from plain crackers or rebaked bread. Approximately 2 tablespoons of crumbs are used for each egg. A teaspoon of cod liver oil is used for every two eggs.

Both the male and female help to feed the little ones. The parent birds predigest and regurgitate their food in the form of pap which is fed to the baby directly. The babies will usually be out of the nest and feeding when less than 3 weeks old. By the time they are a month old, they are usually cracking their own seed but should have egg food for some time.

The young birds should be removed from the feeding cage just as soon as they commence shelling seed. The egg food is continued in decreasing quantities until they are 6 to 7 weeks old.

The Wisconsin Station[26] reported that canaries will do exceptionally well on good chick rations. Over a period of 2 years, they grew well and, upon reaching maturity, produced eggs with a high degree of hatchability. Especially noticeable was the bright yellow color of the birds, no doubt owing to the abundant carotene in the chick mash since this factor is one of the yellow pigments in feathers. On the other hand, a mixture of canary and rape seed, such as commonly used for pet birds, produced either poor growth or actual loss in weight in every case when it made up the only food of experimental animals. Neither did canaries thrive on such a ration. This was probably due to the fact that a diet of seeds is deficient in vitamins and minerals.

OSTRICHES

Very little information is available concerning the feeding of ostriches. The Arizona Station[27] reports having fed daily an average of 3 pounds of alfalfa hay, 1 pound of dried beet pulp, and 1 pound of grain per bird. The grain consisted chiefly of whole wheat, but milo and barley have also been fed. The Texas Station gives the following amounts as a breeding ration per pair of birds:

	Pounds
Alfalfa meal	8
Whole corn	1
Wheat bran	1
Bonemeal	1/2

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CHAPTER 19

ECONOMICS OF FEEDING

The amount of feed which birds consume is a major item in the cost of production. For example, the cost of feed for mature birds represents at least 50 to 60 per cent of the cost of producing eggs. The net return to the producer, however, is influenced also by production and the value of the product as well as the price of the feed.

AMOUNT OF FEED

The amounts of feed which the birds are likely to consume will vary, depending upon conditions. There are a number of factors that influence food consumption.

SIZE OF BIRD. Larger animals (other things being equal) will consume a larger amount of food. Sometimes it is stated that the breed will influence the feed consumed, but it is not so much the breed as it is the actual size of the individual. A 3-pound bird will not consume as much feed as the 4-pound bird, and the 4-pound bird, in turn, not as much as the 5-pound bird under the same conditions of production. That is true because we have an extra amount of body tissue to maintain and, as indicated previously, the maintenance requirements take up by far the greatest proportion of feed consumed. Consequently, such breeds as Plymouth Rocks, Wyandottes, and Rhode Island Reds will consume more feed in a year than Leghorns or Anconas.

INFLUENCE OF PRODUCTION. The heavier the production, either as regards numbers or pounds of eggs laid, the greater the amount of food consumed. The variation in feed consumption throughout the year is due largely to variation in production as shown in the accompanying tabulation of 6-year averages of high versus low pens at the New York State Laying Trials.[1]

The maintenance requirements remain fairly constant for a bird of given size. Additional feed is required for production in direct relation to the number of eggs laid. However, the proportion of feed needed for the production of the eggs is small,

	High Pens		Low Pens	
Month	Feed, lb.	Eggs	Feed, lb.	Eggs
October	8.4	23.0	6.7	12.6
November	8.7	24.5	7.3	15.4
December	9.3	25.3	8.0	17.3
January	9.8	25.2	8.6	17.9
February	9.0	21.9	8.0	14.4
March	9.4	23.9	8.6	14.8
April	9.4	23.5	8.2	14.7
May	9.1	24.3	8.2	14.6
June	8.7	23.2	7.7	12 6
July	8.6	22.8	7.3	10.9
August	8.3	21.4	7.1	9.6
September	5.2	13.7	4 6	5.5
Total	104.5	273.2	91.7	160.8

relative to that required for maintenance. Hence the pounds of feed consumed per dozen eggs produced decreases very rapidly with increased production, as shown in the accompanying estimates for White Leghorn pullets.

RELATION OF FOOD CONSUMPTION TO EGG PRODUCTION IN WHITE LEGHORN PULLETS

Yearly Egg Production	Pounds of Feed			
	For Maintenance	For Eggs	Total	Per Dozen Eggs
80	64.00	7.14	71.14	10.67
120	64.00	10.69	74.69	7.47
160	64.00	14 24	78 24	5.87
200	64.00	17.81	81.81	4.91

This is also shown in the accompanying estimates of feed per bird per year, with various rates of production, as given by Byerly.[2]

Eggs per Year	Weight of Bird		
	4 lb	5 lb	6 lb
0	56.5	65 3	73 6
100	70 5	79 5	87 8
150	77 8	86 6	94 9
200	84 9	93 7	102 0

Similar relations between feed consumption and egg production have been shown by a number of experiment stations.[3–7]

The above relationship occurs because feed consumption is made up of the maintenance needs plus a certain amount of food to produce each egg.

The National Research Council[8] presented a practical guide for the poultryman and feed man (Table 34).

TABLE 34. FEED REQUIRED BY CHICKENS OF DIFFERENT LIVE WEIGHTS FOR MAINTENANCE AND FOR THE PRODUCTION OF 0, 100, 200, AND 300 EGGS, RESPECTIVELY, PER YEAR

	Average Total Feed Required per Bird per Year for Maintenance and the Production of the Indicated Number of Eggs			
Average Live Weight, lb.	0 Eggs per Year, lb.	100 Eggs per Year, lb.	200 Eggs per Year, lb.	300 Eggs per Year, lb.
3.0	47	61	75	89
3.5	52	67	81	95
4.0	57	71	85	99
4.5	61	75	89	104
5.0	65	80	94	108
5.5	70	84	98	112
6.0	74	88	102	116
6.5	78	92	106	120
7.0	81	96	110	124

INFLUENCE OF AGE. Mature fowls (not laying) eat less in proportion to live weight than younger fowls (not laying). Age influences feed consumption probably from two standpoints. First, birds in their second and later years of production are mature and are no longer growing as during the first or pullet year. We find that the birds usually continue to increase in weight nearly to the end of the first laying season. Pullets in the fall mature sexually but they are not mature physiologically. Thus we need to furnish feed for both production of eggs and production of body tissues. Second, the natural performance of the bird is to produce fewer eggs the second year than it did the first and fewer the third than the second so that we have production again as a factor influencing it.

Lamon and Lee[6] show that hens are more efficient in egg production during the first year than in succeeding years, as shown by the pounds of feed required to produce a dozen eggs (Table 35). The difference in actual feed consumption in pounds is not so marked, but, because of the lowered production, the efficiency is decreased.

SEASON AS A FACTOR. Birds will consume larger amounts of feed in colder weather in order to supply the extra heat necessary to overcome the greater difference in temperature between the air and body. Gutteridge, MacGregor, and Pratt[9] reported that the maximum saving in feed accomplished through the

TABLE 35. POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS

Pen	First Year	Second Year	Third Year
1	6.2	9.2	14.1
2	4.9	9.2	16.0
3	7.0	10.3	13.1
4	4.7	5.6	6 0
5	7.3	8.6	11.0
6	8.1	10.6	12 9
Average	6.4	8.9	12.2

decreased requirement of feed for the maintenance of body temperature under heated conditions was 4.7 pounds per bird annually, with a mean saving of 2.85 pounds. The mean inside pen temperature range in the tests was from 32° F. to 58.9° F.

INFLUENCE OF RANGE. Birds on good range have access to a supply of natural food in the grass. Its consumption will decrease the amounts of grain and mash the birds will consume. The difference in food consumption may be as much as 20 per cent.

Similarly birds in cages usually consume less feed than birds kept in pens on the floor.[10]

SUGGESTED AMOUNTS OF FEED

Records at Cornell University indicate that a flock of Leghorns, averaging 4 pounds in weight and not in production, consumed $1\frac{1}{3}$ pounds of feed per hen per week. This represents about 19 pounds per day for 100 hens. This same flock, producing 50 per cent, consumed $1\frac{2}{3}$ pounds per hen per week or about 23 pounds per day for 100 hens. Larger hens will require more feed, smaller ones less. Also more feed will be required for higher levels of production.

The following are given as suggested quantities of feed necessary for average Leghorns (weighing 4 pounds):

Per Cent Production	Pounds of Grain and Mash per Day for 100 Birds
20	21
30	22
40	23
50	24
60	25
70	26
80	27

For heavier birds, such as the American breeds, the amount should be increased by 2 to 3 pounds, or approximately 2 pounds for each pound increase in weight.

The accompanying estimates for feed required per 100 layers a day are given by Byerly.[2]

Per Cent Production	Weight of Birds 4 lb.	5 lb.	6 lb.
0	15.5	17.9	20.2
10	16.9	19.3	21.6
20	18.3	20.7	23.0
30	19.8	22.2	24.5
40	21.2	23.6	25.9
50	22.6	25.0	27.3
60	24.0	26.4	28.7
70	25.4	27.8	30.1
80	26.9	29.3	31.6
90	28.3	30.7	33.0
100	29.7	32.1	34.4

The following formulas have been suggested for calculating the amount of food required.

(1) Total daily feed for 100 birds =

(a) 8.3 + 2.2 × the average weight of the bird + 0.1 × the egg production.

(b) [2] Leghorns

4.11 × the weight + change in body weight + number of eggs divided by 8.

Heavies

3.56 × the weight + change in body weight + number of eggs divided by 8.

(2) Feed per hen per year =

(a) 31.5 + 8 × the weight of the bird + 0.1 times the egg production.

(b) [2] Leghorns

15 × the weight + change in body weight + number of eggs divided by 8.

Heavies

13 × the weight + change in body weight + number of eggs divided by 8.

SOME REPRESENTATIVE RECORDS

YEARLY FEED CONSUMPTION OF MATURE BIRDS. Some variation is found in actual food consumption records, depending

upon the various factors already discussed. In general, however, there is considerable agreement. As an average of seven contests, the Utah Station[11] reported a grain consumption of 44.1 pounds and a mash consumption of 30 pounds per bird, with an average first-year production of 204 eggs. The Maryland Station[12] reported a feed consumption per year of 80.5 pounds for Leghorns, 88.7 pounds for Plymouth Rocks, and 92.2 pounds for Rhode Island Reds. In a 6-year experiment, Cornell[13] gave an average feed consumption of 80.4 pounds for Leghorns, with an average production of 183 eggs.

The accompanying records give average figures for the 5-year period, 1913-1918, of the Connecticut[14] contest.

RELATION BETWEEN FOOD CONSUMPTION AND EGG PRODUCTION
(Connecticut Contest)

	Plymouth Rocks	Wyandottes	Rhode Island Reds	Leghorns
Egg production	153	163	151	162
Lb. grain per bird	45.5	44.3	45.1	43.6
Lb. mash per bird	51.6	45.4	50.1	39.6
Lb. total feed	97 1	89.7	95.2	83.2

Results reported from British Columbia[15] are tabulated.

RELATION BETWEEN FOOD CONSUMPTION AND EGG PRODUCTION
(British Columbia)

	White Leghorns	White Wyandottes	Plymouth Rocks	Rhode Island Reds
Egg production	204	194	182	170
Average wt. (lb.)	4.2	6.4	6.5	5.8
Lb. grain	41.8	43.4	43.4	43.5
Lb. mash	45.5	53.7	56.7	50.5
Lb. total feed	87 3	97.1	97 1	94.0
Lb. oystershell	4 51	3.92	3.57	3.00
Lb. grit	0 25	0.35	0.36	0.31

The 5-year average of the New York Egg-Laying Tests is given in the accompanying table.

FIVE YEAR AVERAGE OF NEW YORK EGG-LAYING TESTS

	White Leghorn	Rhode Island Red	White Plymouth Rock	Barred Plymouth Rock
Production (eggs)	219 1	215 0	182.4	213.6
Weight beginning (lb.)	3.8	5 1	5.1	5.2
Weight end (lb)	4 7	6.4	6 4	6.6
Feed (lb.)	97 4	108 1	91 2	101 4

The food consumption record of 350 two-year-old hens, producing 152 eggs each, in the Advanced Registry at Cornell[16] (1920-21) was:

	Pounds
Grain	39.5
Mash	43.1
Oyster shells	3.1
Grit	0.6
Cabbage	10.9
Sprouted wheat	3.0
Semi-solid buttermilk	1.9

From a survey of feed records[17] on 120 poultry farms in New York State, Darrah reported a feed consumption of 95 pounds for the light breeds and 107.8 pounds for the heavy breeds in 1940-1941. This represented, respectively, 6.9 and 7.9 pounds of feed to produce a dozen eggs. Feed records from 143 farms in 1946-47 indicate an average feed consumption of 108.6 pounds for the light breeds and 116.8 pounds for the heavy breeds. This represents, respectively, 7.2 and 7.5 pounds of feed to produce a dozen of eggs.

MONTHLY FEED CONSUMPTION OF MATURE BIRDS. There is some variation in monthly feed consumption. The difference is due chiefly to the fluctuation in egg production. Table 36 shows monthly food consumption for a vlock at Cornell.[13]

POUNDS OF FEED TO PRODUCE ONE DOZEN EGGS. The economy of producing eggs can be measured by the pounds of feed necessary to produce one dozen eggs. The lighter breeds, in general, are more efficient in this respect. The efficiency is also closely associated with egg production. The efficiency of production goes up with increased egg production. The Maryland Station[12] reports the highest efficiency for a flock of Leghorns which required 3.75 pounds of feed to produce a dozen eggs.

In the New York Laying Trials, flocks producing 217 eggs required 4.56 pounds of feed to produce a dozen eggs whereas the flocks producing 154 eggs required 6.96 pounds. For twelve flocks over a period of 6 years, Cornell[11] shows an average of 6.21 pounds of feed needed to produce a dozen eggs, with a range of 5.35 pounds to 7.92 pounds for the year. The New Jersey Station[1] indicated 6.76 pounds for the average of thirty-two commercial farms. The Oklahoma Station[18] showed that the average feed required to produce one dozen eggs per year for the 5-year egg-laying contests was 2.4 pounds of grain and 2.1 pounds of mash, with a production of approximately 200 eggs.

TABLE 36. FEED CONSUMPTION AND EGG PRODUCTION PER 100 HENS

Month	Grain, lb.	Dry Mash, lb.	Dry Mash in Moist Mash, lb.	Total Feed, lb.	Feed per Day, lb.	Production, %
October	205	129	9	343	21.5	8.4
November	400	292	18	710	23.7	51.8
December	441	219	55	715	23.1	50.0
January	390	247	61	698	22.5	35.7
February	361	281	57	699	24.1	40.3
March	396	321	74	791	25.5	54.1
April	400	374	19	793	26.4	69.1
May	387	399	. . .	786	25.3	70.6
June	346	366	. . .	712	23.7	68.7
July	327	280	32	639	20.6	52.9
August	278	238	123	639	20.6	45.3
September	267	204	121	592	19.7	31.4
October	52	46	24	122	13.5	19.8
Total or average	4250	3396	593	8239	22.3	46.0

There is some difference between the various breeds in this respect (Table 37). Size of bird and production are important factors.

TABLE 37. POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS

	Plymouth Rocks	Wyandottes	Rhode Island Reds	White Leghorns	New Hampshires
Connecticut[14]	7.6	6.6	7.6	6.2	. . .
Maryland[12]	5.7	.	6 1	4.8	. . .
Jull[19]	6.1	8 8	5.6	5.2	6.4

It has already been pointed out that the efficiency of production increases with an increase in egg production. This is shown by the accompanying estimates of Byerly,[2] which give the feed required to produce one dozen eggs.

Percentage Egg Production	Weight of Bird 4 lb	5 lb	6 lb
20	11.0	12 4	13 8
40	6 4	7 1	7.8
60	4 8	5.3	5.7
80	4 0	4 4	4 7

For average conditions on commercial farms Misner and Lee[20] concluded that it required 7 pounds of feed to produce one dozen eggs.

The variations on the monthly basis are much greater than on the yearly basis, owing probably to the greater differences in egg production for the different months. For instance, records at Cornell[13] show monthly variations from 3.95 pounds to 28.60 pounds. The accompanying table is representative of the quantity of feed necessary to produce one dozen eggs for each month throughout the laying year. It will be noted that the amounts are closely associated with the percentage of production.

Month	Pounds of Feed Required to Produce One Dozen Eggs	Per Cent Production
October	28.6	8.4
November	5.5	51.8
December	5.5	50.0
January	7.6	35.7
February	7.2	40.3
March	5.7	54.1
April	4.6	69.1
May	4.3	70.6
June	4.1	68.7
July	4.7	52.9
August	5.5	45.3
September	7.6	31.4
October	12.2	19.8
Average	7.9	46.0

FEED REQUIRED FOR YOUNG STOCK. Food consumption is rather closely related to growth. For example, for the first 26 weeks[21] American-breed pullets consumed 5 pounds more feed than was consumed by Leghorn pullets. However, they also weighed more. When put on the basis of pounds of feed per pound of body weight, the consumption amounts to 6.86 pounds for the Leghorns and 6.48 pounds for the heavy breeds. The American cockerels to 30 weeks of age consumed 4.3 pounds more food than was consumed by the Leghorn cockerels. However, they are considerably heavier so that their food consumption per pound of weight amounts to 6.15 pounds, as compared with 7.51 pounds for the Leghorns. In both instances, the food consumption was relatively greater for the Leghorns, probably because they reached maturity at an earlier age.

These amounts of feed agree closely with those reported by Card and Kirkpatrick,[22] who give a food consumption of approx-

imately 24 pounds for White Leghorns and 27 pounds for Rhode Island Reds, to 24 weeks of age.

The Arizona Station[23] reported that it took 25 pounds of feed to rear a Single Comb White Leghorn pullet to 26 weeks of age, with an average weight of 3 pounds, and that it took 21 pounds of feed to rear a Rhode Island Red pullet, with an average weight of 3 pounds and 6 ounces. The North Carolina Station[24] indicated that it took approximately 23 pounds of feed to put Rhode Island Red pullets into lay.

In a survey of 80 farms in New York[17] in 1940-41 it was found that 23.1 pounds of feed were required to rear a pullet of the light breeds to maturity and 31.4 pounds for a heavy breed pullet. This represented 5.6 pounds and 4.7 pounds of feed to produce 1 pound of pullet for the light and heavy breeds, respectively. In 1947[25] it took an average of 33.5 pounds of feed per pullet on 137 farms.

In Tables 19 and 20 (Chap. 12) are presented the feed consumption for chicks under a normal rearing program. Both large and small strains are represented in the case of Leghorns and in the case of the heavy breeds, New Hampshires, Rhode Island Reds, Barred Cross and Indian River Cross are represented.

The rate of growth, as well as the actual gains, decreases as the chicks grow older. On the other hand, the amount of food consumed gradually increases with the increase in the size of the bird. Therefore the number of pounds of feed required to produce a pound of gain is relatively low at the start and increases as the chicks grow older.[21]

There exists fair agreement on the amount of feed to produce a pound of gain for the different kinds of poultry. It takes approximately 3.0 pounds of feed to produce a pound of gain up to 3 months of age for chickens, ducks, turkeys, and geese and 5.0 to 6.0 pounds of feed to produce a pound of gain up to 24 to 28 weeks of age for chickens, ducks, and turkeys.

Feed efficiency, as expressed by pounds of feed to produce a pound of gain, varies considerably depending upon many factors. Some of these are the kind of ration fed, rate of growth, age, and sex. Feed conversion also varies between breeds and strains of the same breed. The Maryland Station[26] has presented data that strongly indicate that the efficiency of feed utilization is inherited.

FEED REQUIRED FOR BROILERS. In the production of broilers considerable improvement has been made in feed

efficiency. Earlier reports[27] indicate weights of 2¼ to 3½ pounds per bird in 11 to 14 weeks on 3.5 to 4.8 pounds of feed to produce 1 pound of bird. At the present time 3 to 4 pounds of meat are being produced in 9 to 12 weeks with a feed efficiency of 3 pounds or less of feed to produce a pound of meat.[28] Singsen reports an average weight of 2.6 pounds for 8-week-old male chicks in one experiment with a feed efficiency of 2.03 pounds of feed per pound of gain.

Figures reported for large-scale broiler production show the commercial possibilities (Table 38).

Some further reported broiler results are given in Tables 39 and 40.

TABLE 38. GROWTH AND FEED FOR 10–11 WEEK BROILERS

	Average Weight, lb.	*Pounds of Feed to Produce* a Pound of Meat
Lot 1	3.12	2.69
2	3.41	2.72
3	3.49	2.72
4	3.69	2.47
5	3.53	2.77
6	3.50	2.80
7	3.56	2.87
8	3.40	2.85
9	3.14	2.66
10	3.20	2.73
11	3.41	2.67
12	3.02	2.59
13	3.75	2.97
14	3.70	2.87

TABLE 39. RELATION BETWEEN AGE AND FEED CONSUMPTION AND GROWTH OF BROILERS*

Age (weeks)	Body Weight per Bird Cockerels and Pullets Leghorns	Heavies	Total Pounds of Feed (to date) Leghorns Per Bird	Per lb.	Heavies Per Bird	Per lb.
At start	.09	.08				
4	.72	.96	1.37	1.90	1.70	1.77
6	1.37	1.81	3.30	2.41	3.80	2.11
8	2.01	2.74	5.19	2.58	6.63	2.42
10	2.54	3.42	7.90	3.10	8.93	2.61

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TABLE 40. RELATION OF BREED AND AGE TO GROWTH AND FEED EFFICIENCY OF BROILERS

Breed	Age	Average Weight	Feed per Pound of Bird
New Hampshires	12 wks.	4.03	3.05
New Hampshires	12 wks.	3.60	3.16
New Hampshires	10 wks., 6 days	3.30	3.75
New Hampshires (cockerels)	9 wks.	3.02	2.57
		3.03	2.64
		3.15	2.58
		3.09	2.69
White Rocks	12 wks.	4.36	2.88
		4.32	2.72
Heavies	12 wks.	4.50	3+
Crosses mixed	10 wks., 3 days	3.75	3.60
Crosses cockerels	13 wks.	5.25	4.60
Crosses cockerels	11 wks.	3.63	2.92

See also Table 26 (Chap. 12) for the amounts of feed required by heavy breed broilers at various ages.

In a study of Leghorn cockerels as broilers, the Oregon Station[29] showed that the feed required per pound of gain was somewhat less than 3 pounds for battery-reared birds and slightly less than 4 pounds for floor-reared birds. The battery-reared birds were about 1 week ahead of the floor-reared birds in growth.

FEED REQUIRED BY TURKEYS. About 50 pounds of mash and 20 pounds of grain are required to produce a 19-pound turkey at 24 weeks of age under the complete confinement method of rearing. More pounds of feed are required to produce a pound of gain as the poults grow older. This is shown in the accompanying table giving the amount of grain and mash fed per pound of gain in weight.[30] (See also Table 32, Chap. 16.)

Age in Weeks	Average Weight, lb	Pounds of Feed per Pound of Gain: Period	Total
1–4	1.4	1.7	1.7
5–8	4.1	2.4	2.2
9–12	7.6	3.1	2.6
13–16	11.8	3.7	3.0
17–20	15.5	4.7	3.4
21–24	19.1	5.6	3.8
25–28	22.1	8.3	4.5
29–32	24.5	12.2	5.2

Feed consumption and growth data, as reported for Broad Breasted Bronze and Beltsville Small White turkeys by Almquist,[31] are given in Tables 41 and 42.

TABLE 41. GROWTH AND FEED CONSUMPTION FOR BROAD BREASTED BRONZE TURKEYS
(average data for mixed sexes)

Age in Weeks	Weight, lb.	Mash to Date, lb.	Grain to Date, lb.	Total Feed, lb.	Feed Efficiency
2	0.49	0.7	0.0	0.7	1.42
4	1.15	2.5	0.0	2.5	2.18
6	2.15	4.7	0.3	5.0	2.33
8	3.70	8.1	1.1	9.2	2.49
10	5.45	11.8	2.3	14.1	2.58
12	7.40	16.3	3.8	20.1	2.71
14	9.40	21.6	5.3	26.9	2.86
16	11.42	27.2	7.7	34.9	3.06
18	13.38	33.6	10.2	43.8	3.27
20	15.35	40.7	13.2	53.9	3.51
22	17.30	48.0	16.2	64.2	3.71
24	19.20	55.4	22.0	77.4	4.03
26	21.00	62.5	29.0	91.5	4.36

TABLE 42. GROWTH AND FEED CONSUMPTION FOR BELTSVILLE SMALL WHITE TURKEYS
(Average data for mixed sexes)

Age in Weeks	Weight lb.	Mash to Date, lb.	Grain to Date, lb.	Total Feed, lb.	Feed Efficiency
2	0.40	0.6	0.0	0.6	1.50
4	0.85	1.8	0.1	1.9	2.24
6	1.58	3.3	0.5	3.8	2.40
8	2.60	5.3	1.1	6.4	2.46
10	3.82	7.9	1.9	9.8	2.56
12	5.13	10.9	2.9	13.8	2.69
14	6.50	14.3	4.3	18.6	2.86
16	7.72	18.7	5.7	24.4	3.16
18	8.80	23.4	7.7	31.1	3.53
20	9.66	27.6	9.9	37.5	3.88

The average feed consumption and weight of White Holland and Bronze turkeys are reported from Massachusetts[32] in Table 43. The accompanying growth and feed consumption data are reported from Nevada[33] for Broad Breasted Bronze turkeys.

When turkeys are confined, they will consume somewhat more total feed and also require more pounds of feed to produce a pound of gain than when they are allowed to range.[34, 35]

Age	Average Weight, lb.	Total Feed Required, lb.	Cumulative Pounds of Feed per Pound of Gain
First month	1.3	1.4	1.1
Second month	3.9	6.9	1.8
Third month	7.4	15.4	2.1
Fourth month	11.2	26.9	2.4
Fifth month	14.8	41.0	2.8
Sixth month	18.0	57.1	3.2
Seventh month	21.3	78.3	3.7
Eighth month	24.4	103.8	4.2

TABLE 43. CUMULATIVE QUANTITY OF FEED CONSUMED (100 BIRDS) AND WEIGHT OF TURKEYS
(Massachusetts)

Age, weeks	Feed, lb.		Weight, lb.			
			Bronze		White Holland	
	Bronze	White Holland	Male	Female	Male	Female
1	28.26	28.26				
2	58.59	58.59	0.31	0.29	0.34	0.32
3	101.95	101.95				
4	162.51	162.51	0.72	0.63	0.78	0.69
5	234.44	234 44				
6	316.54	316 54	1.38	1.15	1.42	1.23
7	423.24	420.28				
8	559.05	544.17	2.41	1.97	2.33	1.97
9	717.28	705.28				
10	886.81	887.31	3.82	3.24	3.78	3.09
11	1136 42	1116.31				
12	1394.95	1351 34	5.80	4.76	5.38	4.31
13	1690.39	1651.75				
14	2039 79	1992 84	8.14	6.48	7.51	5.78
15	2405.26	2352 83				
16	2794.93	2756 32	10.06	7.69	9.39	6.95
17	3218.73	3201 40				
18	3705 63	3630.22				
19	4160.78	4041 57				
20	4742.65	4575.42	15 02	10 64	13 15	8.88
21	5313 32	5147.56				
22	5797 60	5624.61				
23	6347 91	6122 01				
24	6941 61	6604 32	19 01	12.46	16.46	10.78

Most of the experimental results show fair agreement in the utilization of feed by growing turkeys. The pounds of feed required to produce a pound of gain as reported by a number of stations is as follows:

Station	Pounds of Feed Required to Produce a Pound of Gain
Pennsylvania[36]	
Bronze	4.49
White Holland	4.73
U.S.D.A.[37]	4.12
Oklahoma[34]	
Bronze	3.82
	4.12
	4.45
South Carolina[35]	
Broad Breasted Bronze	4.00
	4.37
Small type Broad Breasted White	4.39
	4.53
Massachusetts[32]	
Bronze	4.41
White Holland	4.85
Cornell[38]	
White Holland	4.19
	4.37
	3.91

Marsden[39] reports that feed consumption of young Bronze breeding hens, fed ad libitum, averaged 3.23 pounds per week per hen for the 8-week winter period; 2.73 pounds per week for the 16-week spring period; and 3.50 pounds per week for the 4-week fall fattening period, after having been held on limited maintenance rations of 1.40 pounds of scratch grain per hen per week during the summer period of 20 weeks. For the 48-week year, the total feed consumed was 111.52 pounds. By adding 4 weeks to the summer maintenance period, the total was 117.12 pounds for the full year of 52 weeks. The males ate nearly twice as much feed per average bird as the females, the requirement for the 48-week year being 226.88 pounds and for the 52-week year 240.88 pounds.

In an economic study of Washington's[40] turkey breeding flocks, it was found that the total amount of feed, excluding shell, fed by growers in different parts of the state did not vary much. For 61 farms it averaged 31.2 pounds of mash, 1.2 pounds of hay, and 40.3 pounds of grain, or a total of 72.7 pounds.

Jull[41] gives the following feed consumption per month during the breeding season:

Broad Breasted Bronze	17–19 pounds
Standard Bronze	16–18 pounds
White Holland	14–16 pounds
Beltsville	11–13 pounds

Parker and Barton[42] report that during a 5 month's period turkey breeding hens and toms consumed 90.5 pounds of feed per bird of which 52 pounds was mash and 38.5 pounds whole grain.

COST OF FEEDING

If the amounts of feed are known for the various purposes, it is easy to figure the cost of production. Costs will be influenced by the actual cost per 100 pounds of the different feeds used to make up the ration. These feed costs vary considerably, depending upon a large number of factors.

Under normal conditions, there are seasonal variations in feed prices which often can be used to advantage.[43] For example, we ordinarily find that grains are at their lowest price soon after harvest. This is true because, as grain is held, the costs of shrinkage, interest, insurance, and destruction must be added. Corn is usually lowest in November to February and highest in July to August; wheat reaches the low point about September to November; oats are lowest during late summer and early fall and highest during May and June. The wheat by-products are usually lowest during the summer and highest during the winter. There is usually a falling off in the demand for meat scraps during the summer months, with a somewhat lower trend in price during July to September.

Any advantage that can be obtained in the price of feeds may mean considerable in the total cost of producing eggs or meat since feed cost represents the largest single item in the cost of production. It usually does not fall much below 50 per cent of the total cost, and in some cases may represent as much as 75 per cent of the cost.

The feed costs on a number of poultry farms for 2 years, as reported from England,[44] represented 60 and 54 per cent of the total cost. On 172 New York farms[45] the feed cost per layer represented 60.0 per cent of the total cost in 1946-47. The feed cost for rearing on commercial poultry farms in New York[46] represented 46 per cent of the total cost in 1940-41. In an economic study of the broiler industry in Western Indiana[47] feed cost was 54.3 per cent of the total cost of producing broilers.

Under normal conditions, feed will represent approximately 60 per cent of the cost of producing eggs and about 50 per cent of the cost of rearing chickens.

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APPENDIX

In the main chapters we discussed the requirements that need to be met in order to make the various rations complete and effective. In the application of these requirements to actual rations it is possible to formulate a large number of mixtures for any specific purpose. These mixtures will vary in different localities depending to a large extent upon the feed ingredients that are available.

In the appendix are given representative rations for definite purposes. Selections have been made of typical rations as recommended in different sections of the United States and Canada. The kinds of rations given are as follows:

(Rations for geese will be found in Chap. 17; for pigeons and other species, in Chap. 18.)

SECTION I. RATIONS FOR YOUNG CHICKENS

CORNELL. (Department of Poultry Husbandry, New York State College of Agriculture, Stencil 205, January, 1953, Recommendations for formulating poultry rations; Stencil 210, February, 1954, Broiler rations.)

Chick Starter Mashes. To be fed as an all-mash ration to chicks until 6 weeks of age. Limited amounts of grain, not to exceed 20 per cent of the daily feed intake, may be fed with it in the following 2 weeks.

Confinement Grower Mashes. To be fed to growing chicks from 8 weeks to maturity in confinement or on poor pasture. Designed for free-choice feeding along with grain.

Pasture Grower Mashes. To be used with free-choice grain feeding only on good pasture supplying abundant succulent forage.

Broiler Starter Mashes. To be fed at least the first 8 weeks of the growth period. They may be used until broilers reach market age. When they have reached that age, a limited amount of grain, not to exceed 20 per cent, can be fed after 8 weeks.

Broiler Grower Mashes To be fed after 8 weeks of age. The all-mash grower ration is fed without grain. The mash to be fed with grain can be fed after 8 weeks with free access to a grain mixture. The grain intake should not exceed 40 per cent of daily feed consumption.

Mixing Mashes. Mash concentrates to be used with local grain (see Section VII)

CORNELL CHICK STARTER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Yellow corn meal	900	895	940	855
Ground wheat	250	200	...	...
Wheat flour middlings	...	...	...	200
Wheat standard middlings	...	...	200	...
Ground barley	...	...	...	200
Ground oats	100	200	100	...
Soybean meal	450	425	350	350
Corn gluten meal	...	...	100	...
Peanut meal	...	...	...	100
Fish meal	50	100	...	...
Fish solubles	...	...	50	...
Meat scrap	50	...	50	100
Corn distillers' dried solubles	50	...	100	...
Dried whey	50	50	...	100
Molasses distillers' dried solubles	...	25	...	...
Dehydrated alfalfa meal	50	50	50	50
Riboflavin supplement to supply (mg. riboflavin)	500 mg.	500 mg.	700 mg.	...
Vitamin B_{12} supplement to supply (mg. B_{12})	1 mg.	...	...	2.5 mg.
D-activated animal sterols (1500 I.C.U./gm.)	0.8	0.8	0.8	0.8
or				
Vitamin feeding oil (300 D, 1500 A)	4	4	4	4
Steamed bonemeal	15	20	25	10
Limestone	30	30	30	30
Salt (iodized)	5	5	5	5
Manganese sulfate (65% feeding grade)	0.4	0.4	0.4	0.4
Antibiotic feed supplement	+	+	+	+
Protein, %	20.5	20.3	20.6	20.5
Calcium, %	1.3	1.2	1.3	1.3
Phosphorus, total, %	0.7	0.7	0.7	0.7
available, %	0.4	0.4	0.4	0.4
Vitamin A,* I.U./lb.	3400	3400	4200	3100
Vitamin D., I.C.U./lb.	270	270	270	270
Riboflavin, mg./lb.	1.6	1.6	1.7	1.7
Vitamin B_{12},† μg./lb.	2	2	2	2

* Assuming use of alfalfa meal containing 100,000 International Units vitamin A activity per pound, and no feeding oil.

† From animal proteins and vitamin B_{12} supplement.

CORNELL CONFINEMENT GROWER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Yellow corn meal	710	575	640	605
Ground wheat	300	200	...	...
Wheat flour middlings	...	...	...	300
Wheat standard middlings	...	300	200	...
Ground barley	...	...	100	300
Ground oats	200	200	200	...
Soybean meal	400	350	350	310
Corn gluten meal	...	...	100	...
Peanut meal	...	...	...	100
Fish meal	50	100	...	...
Fish solubles	...	...	50	...
Meat scrap	50	...	50	100
Corn distillers' dried solubles	100	...	50	...
Dried whey	...	50	50	100
Molasses distillers' dried solubles	...	25	...	...
Dehydrated alfalfa meal	100	100	100	100
Riboflavin supplement to supply (mg. riboflavin)	...	...	...	...
Vitamin B_{12} supplement to supply (mg. B_{12})	1 mg.	...	...	2 mg.
D-activated animal sterols (1500 I.C.U./gm.) or	0.8	0.8	0.8	0.8
Vitamin feeding oil (300 D, 1500 A)	4	4	4	4
Steamed bonemeal	60	60	70	55
Limestone	20	30	30	20
Salt (iodized)	10	10	10	10
Manganese sulfate (65% feeding grade)	0.5	0.5	0.5	0.5
Antibiotic feed supplement	±	±	±	±
Protein, %	20.6	20.4	20.4	20
Calcium, %	1.8	1.8	1.9	1.8
Total phosphorus, %	1.0	1.0	1.0	0.9
available, %	0.7	0.7	0.7	0.7
Vitamin A,* I.U./lb.	5700	5600	5600	5600
Vitamin D, I.C.U./lb.	270	270	270	270
Riboflavin, mg./lb.	1.3	1.5	1.7	1.8
Vitamin B_{12},† μg./lb.	1.9	2.0	2.1	1.8

* Assuming use of alfalfa meal containing 100,000 International Units vitamin A activity and no vitamin feeding oil.

† From animal proteins and vitamin B_{12} supplement.

CORNELL PASTURE GROWER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Yellow corn meal	665	715	665	905
Ground wheat	300	...	200	...
Wheat flour middlings	...	200	...	...
Wheat standard middlings	...	200	200	200
Pulverized oats	300	100	...	100
Ground barley	...	100	200	100
Soybean meal	600	400	450	450
Corn gluten meal	...	100	...	...
Peanut meal	...	...	100	...
Fish meal	...	...	...	50
Meat scrap	...	...	...	50
Corn distillers' dried solubles	...	50	...	...
Dried whey	...	...	50	...
Molasses distillers' dried solubles	...	...	...	25
Steamed bonemeal	85	85	85	60
Limestone	30	30	30	40
Salt (iodized)	20	20	20	20
Manganese sulfate (65% feeding grade)	0.5	0.5	0.5	0.5
Antibiotic feed supplement	±	±	±	±
Protein, %	20.7	20.4	20.5	20.5
Calcium, %	1.9	1.8	1.9	2.0
Total phosphorus, %	1.0	1.0	1.0	1.0
available, %	0.7	0.7	0.7	0.7

CORNELL BROILER STARTER MASHES

Ingredients	lb./ton	lb./ton	lb./ton
Ground yellow corn	975	970	780
Crushed (or coarse ground) wheat	300	. . .	400
Wheat flour middlings	. . .	200	. . .
Pulverized oats	. . .	100	. . .
Soybean meal (solvent)	400	330	420
Corn gluten meal	. . .	100	100
Fish meal	50	100	. . .
Fish solubles	. . .	. . .	50
Meat scraps	100	. . .	50
Corn distillers' dried solubles	50	50	75
Dried whey	50	50	. . .
Molasses fermentation solubles	. . .	. . .	25
Alfalfa meal (minimum 17% protein)	50	50	50
Ground limestone	20	30	30
Dicalcium phosphate	. . .	20	20
Salt	5	5	5
Manganese sulfate (feed grade)	0.5	0.5	0.5
D-activated animal sterols (1500 D)	0.5	0.5	0.5
or			
Vitamin feeding oil (300 D, 1500 A)	2	2	2
Riboflavin supplement to supply (gm riboflavin)	1 gm	1.5 gm	1 gm.
Vitamin B_{12} supplement to supply (mg. B_{12})	4 mg.	4 mg.	4 mg.
Antibiotic feed supplement	+	+	+
Calculated composition:			
Protein, %	20.9	20.9	21.1
Calcium, %	1 2	1.2	1.3
Phosphorus, total, %	0 67	0.77	0.72
available, %	0.42	0.50	0.45
Vitamin A,* USP units/lb.	4500	3500	4200
Vitamin D, I.C U./lb.	170	170	170
Riboflavin, mg./lb.	1.9	1.9	1.9
Vitamin B_{12}, µg./lb	4	4	4
Niacin, mg /lb.	16	17	21
Pantothenic acid, mg./lb.	4.7	4.5	5.0
Productive energy, cal./lb.	925	885	895

* Calculated assuming alfalfa meal contains 100,000 USP units per pound, and without use of vitamin feeding oil in formula.

CORNELL BROILER GROWER MASHES

Ingredients	All-Mash Grower lb./ton	Mash-Grain Grower lb./ton
Ground yellow corn	1125	845
Crushed (or coarse ground) wheat	300	300
Soybean meal (solvent)	250	350
Corn gluten meal	75	100
Fish meal	50	50
Meat scrap	50	100
Corn distillers' solubles	50	50
Dried whey	. . .	50
Alfalfa meal	50	75
Dicalcium phosphate	15	30
Limestone	30	40
Salt	5	10
Manganese sulfate (feed grade)	0.5	1
D-activated animal sterol (1500 D)	0.5	1
or		
Vitamin feeding oil (300 D, 1500 A)	2	4
Riboflavin supplement to supply (gm. riboflavin)	2 gm.	2.5 gm.
Vitamin B_{12} supplement to supply (mg B_{12})	2 mg.	4.5 mg.
Antibiotic feed supplement	+	+
Calculated composition:		
Protein, %	18.1	21.5
Calcium, %	1.3	2.0
Phosphorus, total, %	0.69	0.97
available, %	0.45	0.72
Vitamin A, USP units/lb.	4300	5600
Vitamin D, I.C.U./lb.	170	340
Riboflavin, mg./lb.	2	2.7
Vitamin B_{12}, μg./lb.	2.4	4
Niacin, mg./lb.	16	16
Pantothenic acid, mg./lb.	4	4.7
Productive energy, cal./lb.	960	870

BRITISH COLUMBIA. (University of British Columbia and Department of Agriculture, U. B. C. Feed Formulas for Poultry, Poultry Circular 37, 1954.)

Chick Starting Mash. Designed to be fed to chicks for the first 4 to 8 weeks. Depending upon the rate of growth of the chicks, scratch grain may be fed in gradually increasing amounts, beginning with the fifth week. In case of cannibalism, ground or crushed oats should be self-fed.

Chick Growing Mash. To be fed with scratch grain in approximately equal amounts.

Broiler Mash. All-mash ration to be fed up to 8 weeks of age. Small amounts of scratch grain may be fed from the ninth week until marketing. If white skin, flesh, and fat are preferred, wheat may be used as the only grain. If yellow pigmentation is preferred, then equal amounts of wheat and corn should be fed. In case of cannibalism, whole oats should be fed in small quantities several times a day.

BRITISH COLUMBIA MASHES FOR YOUNG CHICKENS

Ingredients	Chick Starting Mash (per ton) lb.	Chick Growing Mash (per ton) lb.	Broiler Mash (per ton) lb.
Coarse ground wheat	805	770	700
Ground yellow corn	300	200	400
Pulverized oats	100	200	. . .
Ground barley	100	100	. . .
Wheat bran	. . .	100	. . .
Wheat middlings	100	100	200
Fish meal (65–70% protein)	100	50	100
Meat and bone scrap (50% protein)	100	100	100
Dried milk by-products	50	. . .	50
Soybean oil meal (44% protein)	200	150	300
Dehydrated green feed	50	100	40
Distillers' dried solubles or fermentation solubles	50 lb.	50 lb	60 lb.
Ground limestone	30	40	25
Steamed bonemeal	. . .	20	10
Iodized salt	10	15	10
Manganese sulfate	4 oz.	8 oz.	5 oz.
Feeding oil (2250 I.U., A, 300 I.C.U., D per gram)	5 lb.	5 lb.	5 lb.
Choline chloride	1–2 lb.	. .	1–2 lb
Riboflavin	3 gm	3 gm	3 gm.
Vitamin B_{12}	1–2 mg	1–2 mg	4 mg.
Antibiotic	2–10 gm.	2–10 gm.	4–10 gm.

CALIFORNIA. (California Official Random Sample Chicken Meat Production Test, Modesto, 1954.)

MASH FORMULA

Ingredient	Lb./ton
Alfalfa meal, dehydrated	80
Barley, ground	100
Bonemeal, special steamed	15
Corn, yellow ground	600
Fish meal, 65% protein minimum	200
Milo, ground	400
Ground limestone	40
Soybean oil meal, 44% protein minimum	250
Wheat, ground	200
Salt, fine	10
Vitamin A and D oil (2250, 400 D)	2
Butyl fermentation product (3630 mg. riboflavin per lb.)	1/2
Manganese sulfate, feeding grade	1/2
Antibiotic supplement	4

FLORIDA. (University of Florida, 1954.)

FLORIDA MASHES FOR YOUNG CHICKENS

Ingredients	Chick Starting and Growing* Ration, lb.	Broiler Ration, lb.
Wheat bran	3	. . .
Wheat middlings	7	. . .
Yellow corn meal	36	50
Ground oats	5	. . .
Distillers' solubles	3	. . .
Alfalfa leaf meal	6	3
Soybean meal	30	35
Meat scraps	3	. . .
Fish meal	. . .	3
Dried whey	3	3
Steamed bonemeal	2	1.5
Oystershell flour	1	1.5
Salt	1	0.5
Manganese sulfate	5.7 gm.	5.7 gm.
Delsterol	9.0 gm.	9.0 gm.
Vitamin A	. . .	14 gm.
Calcium pantothenate	. . .	1 gm.
Riboflavin	. . .	0.15 gm.
Nicotinic acid	. . .	1.5 gm.
Choline chloride		12.7 gm.
Aurofac 2A	. . .	57 gm.

*Grain to be added after 6 to 8 weeks.

IOWA. (Iowa State College Poultry Department, 1954.)

IOWA RATIONS FOR YOUNG CHICKENS

Ingredient and Protein Content	Starting 20%	Growing 20%	Broiler No. 1	Broiler No. 2
Ground yellow corn	1000	580	1135	1001
Ground whole oats	100	200	...	100
Wheat bran	100	200	...	...
Wheat middlings	100	200	100	100
Dehydrated alfalfa meal (17%)	100	200	50	50
Soybean oil meal (44%)	360	400	450	500
Meat and bone scrap (50%)	100	100	100	50
Fish meal (65%)	50	...	50	50
Dried whey or buttermilk	30	...	50	50
Steamed bonemeal (or equivalent)	20	50	20	40
Ground oystershell or limestone	20	30	10	20
Iodized salt	9	18	9	9
Manganese sulfate	1	1	1	1
Vitamin D concentrate (1500 I.C.U. per gm.)	1	2	1	1
Vitamin A concentrate (2250 I.U. per gm.)	5	5	...	...
Vitamin A-D concentrate (2250 A, 300 D)	...	..	4	4
Riboflavin concentrate (500 mcg./gm.)	...	..	20	20
Riboflavin concentrate (227 mg./lb.)	10	10	...	...
Niacin (grams)	20	20	20	20
Choline chloride (25%)	4	4	4	4
Pantothenic acid (grams)	. .	...	10	10
Vitamin B_{12} (milligrams)	8	4	5	5
Total pounds	2000	2000	2000	2000

Note: The starting mash is to be fed as "all-mash." Grain is to be fed with the other mashes. Vitamins are usually provided in the form of concentrates. Adjustments must be made to compensate for differences in potency. Antibiotic supplements should be fed as supplements to the starting ration. The manufacturers' recommendations will be a satisfactory guide for the level to include with the specific antibiotic concentrate.

Antibiotics should be added to either of the above broiler rations. Penicillin at 2–4 grams per ton or aureomycin, terramycin, or bacitracin at 6–10 grams per ton are the commonly recommended levels. Methionine may be added at the rate of 0.5–1 0 pound per ton.

NEBRASKA. (University of Nebraska, Leaflet 109, 1953.)

NEBRASKA MASHES FOR YOUNG CHICKENS

Ingredients	Chick Starter 53-C, lb.	Broiler Ration 53 Br, lb.
Ground yellow corn	390	580
Wheat shorts or pulverized oats	200	50
Soybean meal	150	150
Alfalfa meal (17% protein plus)	50	50
Meat scraps (50% protein plus)	100	100
Fish meal	20	30
Dried whey	30	. . .
Fish solubles blend	20	. . .
Nebraska Vitamin Concentrate No. 4* or equivalent	10	10
Mineral Mixture No. 57†	30	30

*Each pound of Vitamin Concentrate No. 4 to carry the following minimum values:

Riboflavin	0.2 gm.
Calcium pantothenate	0.4 gm.
Niacin	0.6 gm.
Choline chloride	2.0 gm.
D_3	135,000 I.C.U.
B_{12}	0.3 mg.
Antibiotic (procaine penicillin)	200 mg.
(aureomycin)	1 gm.
(terramycin)	1 gm.
(bacitracin)	1 gm.

†Mineral Mixture No. 57	Parts by weight
Steamed bonemeal (or equivalent)	403
Limestone	403
Salt	161
Trace Mixture No. 1‡	33
	1000

‡Trace Mixture No. 1 carries enough manganese, iodine, iron, cobalt, copper, zinc, and other minor mineral elements when included at a level of 33 parts per 1000, and the complete mineral supplement is used at a level of either 2 or 3 per cent to supplement ingredients as called for in these formulas.

NEW ENGLAND COLLEGE CONFERENCE. (High efficiency poultry feed formulas, revised, June, 1954.)

RATIONS FOR YOUNG CHICKENS

Ingredients	All-Mash Chick Starting and Broiler, lb.	All-Mash Grower, lb.	Mash and Grain (14), Grower, lb.
Ground yellow corn (1)	1100	1050	950
Ground barley or pulverized oats (2)	. . .	200	100
Standard wheat middlings	100	250	200
Soybean oil meal (44%)	500	200	350
Fish meal (60%) (13)	100	50	50
Meat and bone scrap (50%)	. . .	50	75
Alfalfa meal (17%) (100,000 A per lb.)	60	75	100
Distillers dried solubles (3) (4)	50	50	75
Butyl fermentation product (3)(4)	20	20	20
Dicalcium phosphate or equivalent (5)	24	24	36
Ground limestone (feeding grade)	30	25	50
Iodized salt	10	10	15
Dry vitamin D (1500 D per gram) (6)	0 5	0.5	0.7
Manganese sulfate or equivalent (7)	0 25	0.25	0.4
Antibiotic supplement	* (8)	. . .	. . .
Vitamin B_{12} supplement	* (9)	* (9)	* (9)
Niacin	18 gm.	18 gm.	30 gm.
Choline chloride (dry, 25%)	2 5	.	. . .
DPPD (Diphenyl-p-phenylene-diamine)	0 25	* (10)	* (10)
Coccidiostat	* (11)	* (11)	* (11)
Totals (12)	1997 50	2004 75	2022 10

Calculated Analysis

Energy	cal /lb.	898	891	903.0
Protein	%	21.1	16.2	16 2
Fat	%	3 2	3.7	3.6
Fiber	%	3 7	4.2	4.4
Calcium	%	1.36	1.34	1.43
Total phosphorus	%	0 77	0 82	0.77
Readily available phosphorus	%	0 50	0 53	0 50
Manganese	mg /lb	24 0	27.0	27.0
Vitamin A	I U./lb	4308 0	5007.0	4463.0
Vitamin D	I U./lb	170 0	170.0	157 0
Riboflavin	mg /lb	2 4	2.3	1.9
Pantothenic acid	mg /lb	5 3	5.2	4.9
Choline	mg /lb	684 0	431 0	424 0
Niacin	mg /lb	23 0	29.0	26.0

(1) Two to four hundred pounds of coarsely ground wheat may be used to replace an equal amount of corn. Add 0.4 pound of vitamin A and D oil for each 100 pounds of corn removed.

(2) On a nutrient content basis, barley is preferred to oats. Both barley and oats may be replaced by corn if a higher energy level is desired.

(3) 20 pounds of a butyl fermentation product containing at least 250 micrograms of riboflavin per gram (or 113.5 milligrams per pound) and 50 pounds of dried distillers solubles, or 40 pounds yeast or 40 pounds of dried whey plus a riboflavin supplement to furnish not less than 2.0 milligrams per pound in the final ration. To determine the amount of riboflavin supplement to use above, divide the number of milligrams desired by the manufacturer's guaranteed potency. Example: needed to furnish 454 milligrams, using a product having a guaranteed potency of 113.5 milligrams per pound. Solution: 454 divided by 113.5 equals 4 pounds needed in addition to either the yeast or the solubles. This is an example only, not an actual case.

(4) A vitamin concentrate containing not less than 2 grams of riboflavin and 4 grams of pantothenic acid and possibly other vitamins may be used to replace part or all of the fermentation products, and the total weight made up by adding corn meal.

(5) Steamed bonemeal or defluorinated rock phosphate may replace the dicalcium phosphate on a phosphorus basis. Raw rock phosphate containing not more than 3.5 per cent fluorine may replace one-half of the phosphorus in the dicalcium phosphate in the grower.

(6) Vitamin A and D feeding oil may be substituted on a unit basis.

(7) Manganese sulfate (70 per cent feeding grade) or equivalent amount of manganese from other sources.

(8) Use one to five pounds per ton depending upon the product used. Suggested levels are aureomycin, bacitracin, or terramycin, 9 gm.; or procaine penicillin, 2 to 4 grams per ton of finished ration, or equivalent.

(9) Use a vitamin B_{12} concentrate contributing not less than 6 milligrams of vitamin B_{12} per ton of ration.

(10) DPPD (diphenyl-p-phenylenediamine) is an antioxidant used in the chick starting and broiler ration at the 0.0125 per cent level to prevent the appearance of encephalomalacia (crazy chick disease). If desired it may also be added at the 0.0125 per cent level (one-quarter pound per ton) to the other rations to help prevent the destruction of the fat soluble vitamins.

(11) A coccidiosis controlling drug may be used in these rations at the level recommended by the manufacturer.

(12) If an even 2000 pounds is desired, adjust by removing or adding middlings.

(13) If a high salt fish meal is used, omit the added salt.

(14) Feeding ratio equals two parts of mash to one part of grain. Grain mixture contains fifty parts of corn, twenty-five parts of wheat and twenty-five parts of oats.

NORTH CAROLINA. (North Carolina State College of Agriculture and Engineering, University of North Carolina, 1954.)

NORTH CAROLINA RATIONS FOR YOUNG CHICKENS

Ingredients	No. 43 Broiler or Starter 20% lb.	No. 44 Finisher 17% lb.	No. 45 Grower All-Mash 16% lb.	No. 48 Grower Grain-Mash 20% lb
Ground yellow corn	1143	1275	975	910
Pulverized oats	. . .	100	250	100
Wheat middlings	100	. . .	300	200
Corn gluten meal	50	50	. . .	. . .
Alfalfa meal (17% protein) 100,000 A per lb.	75	75	75	100
Fish meal (60% protein)	100	75	50	50
Soybean oil meal (44% protein)	400	300	225	425
Whey, dried	30	30	20	20
Butyl fermentation solubles (250 mg.) riboflavin per gm.)	40	40	20	20
Steamed bonemeal or equivalent	50	50	30	60
Salt	9	9	10	20
Feeding oil (300 D, 1500 A per gm.)	0.5	0.5	0.5	2.50
D-activated animal sterol (1500 D per gm.)	1	1	0.75	1
Meat and bone scrap (50% protein)	. .	. . .	25	75
Antibiotic supplement	grams ++*	grams ++*	. .	. . .
Vitamin B_{12} supplement	6–10 mg.	6–10 mg.	6 mg.	10–12 mg.
Choline chloride (dry 25%)	2	2	. . .	. . .
Niacin	20 gr.	20 gr	18 gr.	20 gr.
Manganese sulfate	0.5	0.5	0.25	0.50
Pulverized oystershells or equivalent	. . .	. . .	20	20
Total	2001+	2008+	2002+	2004+

*Aureomycin, bacitracin, penicillins, and terramycin are added to broiler mashes for the purpose of stimulating growth in young chickens. Two arsonic compounds are also being used commercially in broiler feeds to stimulate growth in young chickens. The quantity of antibiotic as well as arsonic compound added to a broiler mash should be governed by the recommendation of the manufacturer.

Suggestions on feeding:

1. Self-feed the chicks broiler or starter mash without grain for 7 weeks. Replace the broiler mash with the finisher at 8 weeks, and feed it until the broilers are marketed. Some broiler growers, instead of using a finishing mash, prefer to feed the broiler mash throughout the growing period and finish the birds by feeding all the cracked yellow corn the broilers will clean up in 20 to 30 minutes in the late afternoon. The feeding of corn is started at 8 weeks of age.

2. Self-feed the replacement stock starter or broiler mash without grain for 7 weeks. Change the replacement stock from starter to grower at 8 weeks of age.

3. Do not feed a scratch mixture or separate grains with the all-mash 16 per cent protein mashes.

4. Feed a scratch mixture or separate grains with the 20 per cent protein mashes.

5. Keep crushed oystershells or limestone before the birds that are fed the 20 per cent protein grower. It is not necessary to feed crushed oystershells or limestone to the chickens receiving the all-mash 16 per cent protein mashes.

6. The growing chickens fed a scratch mixture or separate grains should have access to insoluble hard grit or gravel. Crushed granite, quartz, and feldspar are examples of hard grit.

ONTARIO AGRICULTURAL COLLEGE. (S. J. Slinger, W. F. Pepper, and J. R. Cavers. O.A.C. Chicken Starting, Growing, and Fattening Feed Formulas, O.A.C. Circular 142, revised, January, 1954; O.A.C. Broiler Feed Formulas, O.A.C. Circular 143, revised, June, 1953.)

Starter Mash. The feeding of chick grain as the sole feed, at the start, is often helpful in preventing pasting-up. It is recommended that chick grain not be fed for longer than 24 hours. This mash contains about 20 per cent protein (N × 6.25). It is designed to be fed for the first 8 weeks of life. It should be used as an all-mash ration for the first 7 weeks. For the period from 7 to 8 weeks of age a small amount of whole oats may be fed in conjunction with the mash. The feeding of insoluble grit is particularly important when grain feeding begins.

Chick Starter Concentrate. This concentrate when mixed in the proportion of 100 parts of concentrate to 225 parts of ground grains will make a chick starter mash containing about 20 per cent protein (N × 6.25). To have the chick starter mash similar in composition to the mash shown it is suggested that the ground grains be used in the proportions of 4 parts wheat, 1 part corn, 1 part barley, and 1 part oats by weight. The resultant starter mash should be used as already indicated for the chick starter mash.

Chick Confinement Grower Mash. This mash contains about 19 per cent protein (N × 6.25). It is designed to be fed to confined birds in conjunction with whole grain from 8 weeks of age until the birds begin to lay. The mash should be fed free choice, and grain should be hand fed in accordance with mash consumption, gradually increasing the level of grain feeding as the birds grow. As a guide, it is suggested that by 12 weeks of age the birds should be eating 75 parts of mash and 25 parts of grain; by 14 weeks of age, 60 of mash and 40 of grain; and at 16 weeks of age, 50 of mash and 50 of grain. For confinement-reared pullets it is not desirable at any time to have the grain consumption greater than that of mash.

Chick Confinement Grower Concentrate. This concentrate when mixed in the proportions of 100 of concentrate to 225 of ground grains will result in a confinement grower mash containing about 19 per cent protein. To make a grower mash similar in composition to the confinement mash presented, the ground grains should be used in the proportions of 6 parts wheat, 3 parts barley, 3 parts oats, and 2 parts corn by weight. The confinement grower mash made in this way should be used in the manner indicated previously.

Chick Range Grower Mash. This mash contains about 17.7 protein (N × 6.25). It is designed to be fed to birds on range from about 8 weeks of age until egg production begins. Mash should be freely accessible and grain limited until the birds are 12 weeks of age. After this time mash and grain may be made freely available in separate hoppers. If the range is succulent and short, the birds will gradually tend to consume more grain in proportion to mash as they grow. As a guide they should be consuming about 50 parts of mash to 50 parts of grain at 12 weeks of age, 40 parts of mash to 60 parts of grain by 16 weeks, and 30 parts of mash to 70 parts of grain by 20 weeks of age. It may be necessary to adjust these proportions somewhat during the latter part of the growing period, depending upon the rate of maturity. For birds reared out of doors but with little or no pasture available, the mash designed for confinement-reared birds should be used in preference to the range grower mash.

Chick Range Grower Concentrate. This concentrate when mixed in the proportions of 100 parts of concentrate to 300 parts of ground grains will make a range grower mash containing about 17.7 per cent protein (N × 6.25). To have a mash similar in composition to the range grower mash shown, the ground

grains should be used in the proportions of 7 parts wheat, 3 parts barley, 3 parts oats, and 2 parts of corn by weight. The range mash made in this way should be used as suggested above for the range grower mash.

Broiler Feed. Regardless of the program used (Number 1, 2, or 3) the birds should be fed the starter mash for the first 6 weeks of age. At this time they should be changed to the formulas listed under 7 to 10 weeks. The change should be made gradually over a period of about 3 days. They should be fed this diet until they are 10 to 11 weeks old if they are to be marketed as broilers. The diets listed under "11 to 15 weeks" were devised for light roasters.

The feeding of chick grain as the sole feed for 24 hours is often helpful in preventing pasting-up. After this time no grain or additional minerals should be fed in conjunction with these mashes. Mash should be available for from 12 to 14 hours a day.

Insoluble grit such as granite should be sprinkled on the feed twice weekly or made freely accessible to the birds in separate hoppers. Chick-size grit is advisable for the first 6 weeks, after which grower-size grit is preferable.

Clean, fresh water should be easily accessible at all times. Placing waterers close to all feed hoppers is a distinct advantage.

O.A.C. CHICKEN STARTING AND GROWER MASHES

Ingredients	Chick Starter Mash, lb.	Chick Starter Concentrate, lb.	Chick Confinement Grower Mash, lb.	Chick Confinement Grower Concentrate, lb.	Chick Range Grower Mash, lb.	Chick Range Grower Concentrate, lb.
Ground wheat	760	...	600	...	700	...
Ground yellow corn	200	...	200	...	200	...
Ground barley	200	...	300	...	300	...
Pulverized oats	200	...	300	..	300	...
Dehydrated alfalfa meal (100,000 I.U. vitamin A activity/lb.) or cereal grass	63	200	93	300	50	207
Meat meal (50% protein)	20	60	70	240	60	240
Fish meal (65% protein)	50	160	25	80	20	80
Dried buttermilk or skimmilk	40	120	40	130	40	160
Soybean oil meal (44% protein)	400	1275	300	1000	250	1000
Ground limestone	15	60	20	90	25	100
Steamed bone meal or equivalent	40	90	40	120	45	165
Iodized salt	10	30	10	34	10	40
Vitamin A oil (10,000 I.U./gm.)	0.75	2	0.75	2	0.75	2
Dry vitamin D_3 (1650 I.C.U./gm.)	1	3	1	3	1	3
Manganese sulfate (feed grade)	0.25	0 75	0.4	1.25	0.4	1.5
	gm.	gm.	gm.	gm.	gm.	gm.
Riboflavin	2	7	3	10	2	8
Antibiotic*	2–10	6–30	3–15	10–50	2–10	8–40
Arsonic acid†	45–90	135–270	45–90	135–270	45–90	135–270
	mg.	mg	mg.	mg.	mg.	mg.
Vitamin B_{12}	3	10	3	10	3	12
Calculated analysis:	%	%	%	%	%	%
Min. crude protein	20.4	38.6	19 0	35.5	17.7	35.2
Min. crude fat	2.3	1.6	2.6	2.1	2.6	2 1
Max. crude fiber	5.4	6.9	6.1	7.6	5.6	6.3
Calcium	1.2	3.3	1 4	5 0	1.5	5.7
Total phosphorus	0.8	1.4	0.8	1.8	0.8	2.1
Inorganic phosphorus	0.48	1.08	0 56	1.56	0.56	1.85

*If penicillin is used, the lower level is satisfactory. If aureomycin, terramycin or bacitracin are used, the higher levels should be employed.

†Either 3-nitro, 4-hydroxyphenylarsonic acid at the lower levels indicated or arsanilic acid or sodium arsanilate at the higher levels may be used.

Substitutions. An equal mixture of wheat shorts and bran may be used to replace ground wheat or barley. For the starting diet an equal-parts mixture of wheat middlings and wheat shorts is more desirable.

Dried whey may replace dried buttermilk or dried skimmilk. For every 40 pounds of dried milk replaced, increase the amount of soybean oil meal by 30 pounds and reduce the ground wheat by 30 pounds.

Vitamin A feeding oil and dry vitamin D_3 may be replaced by fish oil on an equal unitage basis. The vitamin A oil may be replaced by dry vitamin A products or by vitamin A oils of other potency on an equal unitage basis.

Steamed bonemeal may be replaced by defluorinated rock phosphate. Other calcium and phosphorus carriers may also be used. Replacement should be based on the calcium and phosphorus content.

Manganese sulfate may be replaced by other manganese carriers to supply equal levels of manganese.

Ground limestone may be replaced by calcium carbonate.

O A.C. BROILER FEED FORMULAS

Ingredients	Program No. 1 Age in Weeks 0-6	7-10	11-15	Program No. 2 Age in Weeks 0-6	7-10	11-15	Program No. 3 Age in Weeks 0-6	7-10	11-15
	lb	lb.	lb	lb.	lb	lb	lb	lb	lb.
Ground wheat	1000	900	900	1200	1100	1100	280	300	300
Ground yellow corn	200	550	600	100	400	450	900	1055	1100
Pulverized oats	–	–	100	–	–	100	–	–	100
Soybean oil meal (44% protein)	570	350	230	–	–	–	590	450	330
Soybean oil meal (50% protein)	–	–	–	470	300	180	–	–	–
Soybean oil	20	20	–	20	20	–	20	20	–
Dehydrated alfalfa meal or cereal grass	40	40	40	40	40	40	40	40	40
Meat meal (50% protein)	20	20	20	20	20	20	20	20	20
Fish meal (65% protein)	60	40	40	60	40	40	60	40	40
Dried buttermilk or skimmilk	40	30	30	40	30	30	40	30	30
Ground limestone	10	15	15	10	15	15	10	10	10
Steamed bonemeal	35	25	20	35	25	20	35	30	25
Iodized salt	5	5	5	5	5	5	5	5	5
Vitamin A oil (10,000 I U /gm)	0 75	0.75	0.75	0 75	0 75	0 75	0 75	0 75	0.75
Dry vitamin D_3 (1500 I C U /gm)	1	1	1	1	1	1	1	1	1
DL Methionine (feed grade)	0 5	0 5	–	0 5	0 5	–	0 5	0 5	–
Manganese sulfate (feed grade)	0 3	0 3	0 3	0 3	0 3	0 3	0 35	0 35	0 35
	gm	gm	gm	gm	gm	gm	gm	gm.	gm
Riboflavin	3	2	2	3	2	2	3	2	2
Niacin	–	10	10	–	5	5	15	15	15
Antibiotic*	2–10	2–10	2–10	2–10	2–10	2–10	2–10	2–10	2–10
Arsonic acid†	45–90	45–90	45–90	45–90	45–90	45–90	45–90	45–90	45–90
	mg	mg	mg	mg	mg	mg	mg	mg	mg
Vitamin B_{12}	5	3	3	5	3	3	5	3	3
Calculated analysis	%	%	%	%	%	%	%	%	%
Min crude protein	23 4	18 4	16 6	23 4	18 9	16 7	21 9	18 8	16 8
Min crude fat	3 9	4 1	3 3	4 1	4 2	3 4	4 0	4.0	3 2
Max crude fiber	4 4	3 8	4 1	3 1	3 2	3 7	4 2	3 9	4 1
Calcium	1 0	0 9	0 8	1 0	0 9	0 8	1 0	0 9	0 8
Total phosphorus	0 8	0 6	0 6	0 8	0 6	0 6	0 8	0 6	0 6
Inorganic phosphorus	0 47	0 36	0 33	0 47	0 37	0 33	0 47	0 39	0 35

*Penicillin, 2 grams, aureomycin, terramycin or bacitracin, 10 grams

†3 nitro-4 hydroxyphenylarsonic acid, 45 grams, arsanilic acid or sodium arsanilate, 90 grams

TEXAS. (Agricultural and Mechanical College of Texas, 1954)

TEXAS RATIONS FOR YOUNG CHICKENS

Ingredients	Chick Starter and Broiler All-Mash %	Chicken Grower All-Mash %	Broiler Finisher All-Mash %
Ground milo	27*	39*	25*
Ground yellow corn	27 1/2*	25*	44*
Soybean oil meal (44% protein)†	30	22	18
Fish meal (60% protein)	2 1/2	2	2 1/2
Fish solubles	2 1/2	...	...
Dried whey	2 1/2	3	2 1/2
Dehydrated alfalfa leaf meal	4	5	4
Steamed bonemeal or equivalent phosphorus supplement	2	2	2
Ground limestone or oystershell	1 1/2	1 1/2	1 1/2
Salt	1/2	1/2	1/2
Supplements‡			

*Milo and corn can be used interchangeably depending upon price and availability.

†Soybean oil meal may be replaced by cottonseed meal meeting the following quality specifications: (1) containing no more than 0.1 per cent free gossypol; (2) having a nitrogen solubility of at least 70 per cent in 0.02 N sodium hydroxide Ten per cent in the starter and broiler all-mash; 8 per cent in the chicken grower, all-mash; 6 per cent in the all-mash broiler finisher.

‡To be added per ton of feed·

1. Manganese sulfate: 1/2 pound.
2. Antibiotics: Use either 10 grams of aureomycin, 10 grams of bacitracin, 10 grams of terramycin or 4 grams of penicillin. A combination of two, three or four of the antibiotics may be used In making up the combination, use a proportionate part of the above given levels on a per ton basis.
3. Vitamin A: 2,270,000 International units Any source of vitamin A available may be used just so the total number of units added per ton is that given above
4. Vitamin D_3: 1,200,000 International chick units.
5. B vitamins: 4 gm. riboflavin, 10 gm. calcium pantothenate (Dextrorotatory); 25 gm. niacin, 100 gm. choline chloride. It will probably be necessary to obtain choline chloride in the dry form as a 25 per cent supplement.
6. Vitamin B_{12}: 6 milligrams.
7. Methionine· 1 pound
8. Arsonic acids: Add level according to manufacturers' recommendations (add to broiler, broiler finishing, and starting rations only).

WASHINGTON. (Washington Poultry Feed Formulas, Poultry Science Department, State College of Washington, Ext. Mimeo. 1057, 1065, and 1582, 1954.)

CHICKEN FRYER AND STARTER MASHES

Ingredients	1 %	2 %	3 %	4 %	5 %	6 %
Ground yellow corn or milo*	64.7	63.7	59.8	65.8	66.5	68.8
Dehydrated alfalfa or grass (carotene, 12mg./100gm.)	2.5	2.5	2.5	2.5	2.5	2.5
Fish meal (70% protein)	5.0	3.5	2.0	3.5	3.5	10.0
Soybean oil meal (44% protein)	24.0	26.5	28.8	20.7	18.2	15.3
Meat and bonemeal (50% protein)	...	...	...	5.0	7.5	...
Whey, dried	...	...	3.0	...	...	...
Limestone or shell flour	1.6	1.5	1.6	1.6	1.5	1.6
Steamed bonemeal or defluorinated phosphate	1.9	2.0	2.0	0.6	...	1.5
Salt (iodized, fine)	0.3	0.3	0.3	0.3	0.3	0.3
Add the following to each ton of feed						
Riboflavin (grams)	1.0	1.0	0.22	1.0	1.0	1.0
Vitamin D_3, millions of I.C.U.	0.27	0.27	0.27	0.27	0.27	0.27
Methionine (97-100% pure)	0.5	0.5	0.5	0.5	0.5	0.5
Manganese sulfate, lb. (100% pure)	0.25	0.25	0.25	0.25	0.25	0.25
Antibiotic†						

Suggested analysis: protein, 20 per cent; calcium, 1.4 per cent; phosphorus, 0.7 per cent; vitamin A, 1200 International units per pound; vitamin D_3, 135 International chick units per pound; and riboflavin 1.6 milligrams per pound.

The suggested method of feeding fryers is as follows: During the first 2 weeks keep mash or crumbles only before the chicks. From 2 weeks to market age feed mash, crumbles or pellets. An amount of scratch that will be cleaned up in 20 minutes may be fed once a day after 6 weeks of age.

The suggested method of feeding replacement stock is as follows: During the 8-week starting period keep mash, crumbles or pellets (after second week) always before the chicks. Start grain feeding the fourth week. Keep grain in hoppers continuously or feed all they will eat three times daily in the litter or yard. Feed granite or silica grit of the proper size 1 day each week.

*Up to 20.0 per cent of ground wheat, ground barley, or finely ground oats may be used to replace an equivalent amount of corn or milo; however, substitutions of oats and barley will noticeably decrease feed efficiency.

†If using diamine or procaine penicillin use at rate of 3 grams per ton. If using aureomycin, bacitracin or terramycin use at rate of 10 grams per ton.

WASHINGTON CHICKEN DEVELOPER MASHES
(8 weeks to maturity)

Ingredients	1 %	2 %	3 %	4 %	5 %	6 %
Ground corn or ground milo	...	...	...	...	...	66.1
Ground grains*	48.8	49.6	51.9	46.7	48.9	...
Wheat mixed feed (mill-run)*	20.0	20.0	20.0	20.0	20.0	...
Fish meal (70% protein)	2.5	...	2.5	...	2.5	2.5
Meat and bonemeal (50% protein)	...	5.0	5.0	...	...	...
Soybean oil meal (44% protein)	12.7	10.7	6.3	17.1	7.6	20.0
Cottonseed meal (43% protein; maximum free gossypol, 0.003%)	...	...	...	. .	5 0	...
Dehydrated alfalfa or grass (carotene, 12 mg./100 gm.)†	10.0	10 0	10.0	10 0	10 0	5.0
Limestone or shell flour	2 0	1.5	1.5	2.0	2 3	1.6
Steamed bonemeal or defluorinated phosphate	3 2	2 4	2.0	3 4	2.9	4.0
Salt (iodized, fine)	0.8	0.8	0 8	0.8	0.8	0.8
Add the following to each ton of feed						
Vitamin A, millions I.U.	.	...	.	.	...	6.9
Vitamin D_3, millions I.C.U	0.27	0.27	0.27	0.27	0.27	0.27
Riboflavin (grams)	1.6	1.6	1.6	1 6	1.6	2.5
Vitamin B_{12} (milligrams)	...	.	..	4.8	...	...
Manganese sulfate lb. (100% pure)	0.4	0.4	0.4	0.4	0 4	0.4

Suggested analysis: protein, 17.5 per cent; calcium, 2.0 per cent; phosphorus, 1.0 per cent; vitamin A, 8000 International units per pound; vitamin D_3, 540 International chick units per pound; riboflavin, 2.0 milligrams per pound.

These mashes are formulated to be fed free choice with whole grains Adequate vitamins are provided to meet requirements when pullets consume up to 75 per cent whole grain. Granite or silica grit should be fed one day each week.

*Ground corn, milo, wheat, barley or oats may be used singly or in any combination with 0 to 20 per cent millrun as long as the combined amounts of barley, oats, and millrun to not exceed 55 per cent of the mash

†Dehydrated alfalfa or grass may be reduced 5 per cent in rations 1 through 5; and the ground grain may be increased by 5 per cent if vitamin A is added at the rate of 6 9 million International units per ton of mash Less vitamin A supplement will be required if a higher carotene dehydrated alfalfa or grass is used

WASHINGTON ALL INCLUSIVE DEVELOPER MASHES

Ingredients	No. 1 %	No. 2 %
Ground grains and millrun*	74.6	75.6
Fish meal (70% protein)	2.0	2.0
Meat and bonemeal	...	5.0
Soybean oil meal (44% protein)	15.0	10.0
Dehydrated alfalfa or grass (carotene 12mg./100g.)	5.0	5.0
Limestone or shell flour	1.7	1.3
Steamed bonemeal or defluorinated phosphate	1.7	0.6
Salt (iodized, fine)	0.5	0.5
Add the following to each ton of feed		
Vitamin D_3, millions of I.C.U.	0.27	0.27
Manganese sulfate, lb. (100% pure)	0.3	0.3

Suggested analysis: protein, 16 per cent; riboflavin, 0.9 per cent, milligrams per pound; vitamin A, 2000 International units per pound; vitamin D_3, 135 International chick units per pound; phosphorus, 0.7 per cent; calcium, 1.4 per cent.

These diets are designed to be used as the only feed fed to the birds.

*Ground corn, milo, wheat, barley, or oats may be used singly or in any combination with 0-10 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 35 per cent of the diet.

WISCONSIN. (University of Wisconsin, 1954.)

WISCONSIN RATIONS FOR YOUNG CHICKENS

Ingredients	20% Chick Starter and Broiler Mash	Chick Grower with Good Pasture
Ground yellow corn	515	350
Wheat bran	50	100
Wheat middlings	50	150
Pulverized oats	. . .	150
Dehydrated alfalfa meal	50	. . .
Meat scrap	50	50
Fish meal	. . .	. . .
Soybean oil meal	250	150
Steamed bonemeal or defluorinated rock phosphate or equivalent	10	20
Chick size oystershell or hi-calcium limestone	20	20
Iodized salt	5	10
Riboflavin*	Yes	No
Vitamin B_{12} supplement†‡	Yes	No
Antibiotic feed supplement†	Yes	No
400 D Fish oil or powder§	1 1/2	. . .
Manganese sulfate (feeding grade)	1/4	. . .

Grains to be fed free choice with all above rations, except 20 per cent chick starter and broiler mash.

Oystershell and granite grit fed free choice in all rations.

* Riboflavin: 1.0 milligrams per pound of feed from any source.

† Use according to manufacturers' directions.

‡ Some commercial supplements do not meet the minimum standards for this product but may be good sources.

§ Based on A.O.A.C. units. If new International chick unit is used, 75 per cent of the above will be sufficient.

WISCONSIN RATIONS FOR BROILERS

Ingredients	I	Ia	II	III	IV	V	VI	VII
Ground yellow corn	43	43	43	38	43	43	44	43
Wheat bran	5	5	5	5	5	5	5	5
Wheat middlings	5	5	5	5	5	5	5	5
Soybean oil meal	22	32	32	32	30	20	26	27
Meat scrap	...	...	...	...	...	...	5	...
Fish meal	...	...	...	...	2	2	...	...
Fish solubles	3	3	...	...	...	...	...	...
Dried yeast	...	...	...	...	...	...	...	5
Dried whey (fortified)	...	...	...	5	...	...	...	...
Dehydrated alfalfa meal	5	5	5	5	5	5	5	5
Steamed bonemeal	2	2	2	2	2	2	1	2
Chick size oystershell	2	2	2	2	2	2	2	2
Granite grit	2	2	2	2	2	2	2	2
Iodized salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Corn gluten meal	10	...	...	...	...	10	...	...
Feeding oil (300 D)*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Riboflavin supplement†	+	+	+	...	+	+	+	+
$MnSO_4$ oz./100 lb. (feeding grade)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin B_{12} supplement‡	...	...	+	+	+	+	+	+
Antibiotic feed supplement‡	+	+	+	+	+	+	+	+

* New International chick unit (I.C.U.)

† To supply 1 milligram riboflavin per pound of feed from any source.

‡ Use according to manufacturer's directions. Certain supplements not of antibiotic origin may give equivalent growth.

SECTION II. RATIONS FOR LAYERS

CORNELL. (Department of Poultry Husbandry, New York State College of Agriculture, Stencil 205, January, 1953.)

Cornell Layer Mashes. To be fed with approximately equal grain intake according to any good mash-grain feeding program.

Mixing Mashes. Mash concentrates to be used with local grain (see Section VII).

CORNELL LAYER MASHES

	Lb./ton	Lb./ton	Lb./ton	Lb./ton
Yellow corn meal	795	580	750	630
Ground wheat	300	300	...	...
Wheat flour middlings	...	...	300	200
Wheat standard middlings	...	300	...	200
Pulverized oats	100	...	200	...
Ground barley	...	...	...	200
Soybean meal	475	425	370	380
Corn gluten meal	...	...	...	50
Peanut meal	...	100	...	...
Fish meal	...	...	50	50
Meat scrap	100	...	50	...
Corn distillers' dried solubles	...	...	50	...
Dried whey	...	...	...	50
Molasses distillers' dried solubles	...	25	...	...
Dehydrated alfalfa meal	100	100	100	100
Riboflavin supplement to supply (mg. riboflavin)	400 mg.	200 mg.	200 mg.	...
D-activated animal sterols (1500 I.C.U./gm.)	2	2	2	2
or				
Vitamin feeding oil (300 D, 1500 A)	10	10	10	10
Steamed bonemeal	90	120	90	100
Limestone	20	20	20	20
Salt (iodized)	20	20	20	20
Manganese sulfate (65% feeding grade)	0.5	0.5	0.5	0.5
Protein, %	20.6	20.7	20.5	20.6
Calcium, %	2.3	2.3	2.2	2.1
Total phosphorus, %	1.2	1.2	1.2	1.2
Available, %	0.9	0.9	0.9	0.9
Vitamin A,* I.U./lb.	5800	5600	5800	5600
Vitamin D, I.C.U./lb.	680	680	680	680
Riboflavin, mg/lb.	1.3	1.3	1.3	1.6

* Assuming use of alfalfa meal containing 100,000 units of vitamin A activity per pound and no vitamin feeding oil.

CORNELL. (All-mash ration for hens, F. W. Hill, Cornell Feed Service, November, 1952.)

	lb.
Yellow corn meal	945
Ground wheat	500
Alfalfa meal (17%)	40
Soybean meal (44%)	250
Fish meal	50
Meat scraps (50%)	50
Distillers' dried solubles	50
Dried whey	50
Dicalcium phosphate	25
Ground limestone	30
Salt	10
Manganese sulfate	0.5
Vitamin A oil (4500/gm.)	1
Dry D (1500/gm.)	1
	2002.5

Calculated composition:

Protein, %	16.1
Calcium, %	1.4*
Phosphorus, %	0.78
Available phosphorus, %	0 56
Vitamin A, I.U./lb	4400.
Vitamin D, I.C U./lb.	340.
Riboflavin, mg./lb.	1 3

*Calcium level insufficient to meet requirements for high egg production. Free-choice feeding of oystershell or other calcium supplement necessary

BRITISH COLUMBIA. (University of British Columbia and Department of Agriculture U.B.C. Feed Formulas for Poultry, 1954, Poultry Circular 37.)

Pullet Laying Mash. To be fed with scratch grain: approximately 60 parts of mash to 40 parts of grain. Clean oystershell should be freely accessible.

All-Mash Laying Ration. This is an all-mash ration which need not be supplemented with oystershell. It may be fed either to birds in laying cages or birds ordinarily housed.

BRITISH COLUMBIA LAYING MASHES

Ingredients	Pullet Laying Mash (per ton), lb.	All-Mash Laying Ration (pelleted) (per ton), lb.
Coarse ground wheat	800	1035
Ground yellow corn	100	300
Pulverized oats	200	100
Ground barley	100	100
Wheat bran	100	...
Wheat middlings	100	...
Fish meal (65-70% protein)	100	50
Meat and bone scrap (50% protein)	200	...
Soybean oil meal (44% protein)	100	150
Dehydrated green feed	100	80
Distillers' dried solubles or fermentation solubles	...	50
Ground limestone	50	70
Steamed bonemeal	20	50
Iodized salt	20	10
Manganese sulfate	8 oz.	4 oz.
Feeding oil (2250 I.U., A; 300 I.C.U., D per gram)	10	5
Choline chloride	...	1-2
Riboflavin	2 gm.	1 gm.
Recommended protein level	20%	16%

CALIFORNIA. (California Egg Laying Test, Modesto, 1954.)

LAYING MASH FORMULA

Ingredients	Lb./ton
Alfalfa meal, dehydrated	150
Barley, ground	200
Corn, yellow ground	400
Fish meal, 70% protein minimum	158
Meat and bone scraps, 50% protein minimum	50
Milo, ground	200
Ground limestone	40
Wheat, ground	200
Soybean oil meal, 44% protein	250
Wheat bran	300
Whey, dried	50
Salt, fine	10
Vitamin D source (1500)	2
Manganese sulfate, 85% pure	1/4
Riboflavin (or concentrate to provide this amount)	1 gm.

Free choice barley, granite grit, oystershell

CONNECTICUT. (A high-efficiency ration for laying and breeding hens, E. P. Singsen, L. D. Matterson, and Anna Kozeff, Conn. Bul. 286, 1952.)

	Pounds
Ground yellow corn	1223
Standard wheat middlings	250
Soybean oil meal	200
Meat scrap (50%)	100
Fish meal (60%)	40
Alfalfa meal (100,000 A/lb.)	50
Butyl fermentation product (250 riboflavin/lb)	20
Steamed bonemeal	40
Ground limestone	60
Salt	10
Vitamin A and D feeding oil (2000 A–400 D/gm.)	5
Vitamin B_{12} concentrate (3 mg /lb.)	2
Manganese sulfate	0.25
Nicotinic acid	20 gm.
	2000 25

This ration to be fed as an all-mash ration or as all-mash and pellets. The pellets are made from the same mash.

FLORIDA. (University of Florida, 1954.)

Ingredients	Laying and Breeding Ration lb.	National Egg Laying Test lb.	Low-Energy All-Mash lb.	Cage-Layer High-Efficiency All-Mash lb.
		Mash		
Yellow corn meal	200	100	287	52
Shorts	100	100	287	10
Wheat bran	100	100	100	. . .
Ground oats	100	100	287	10
Soybean meal	150	70	70	10
Meat scrap	100	20	20	5
Fish meal	. . .	15	15	2.5
Dried whey	80	10	10	
Alfalfa leaf meal	100	25	25	5
Steam bonemeal	30	10	10	3
Shell	20	7	7*	2
Salt	10	3	3	0.25
Delsterol (vitamin D)	450 gm.	. . .	†	
Vitamin A	454 gm.	. . .	‡	
Vitamin supplement	. . .	. . .	. . .	§
		Grain		
Whole yellow corn	100	100		
Wheat	100	200		
Oats	100	100		

* Keep oystershell in hopper.
† 200 units per pound.
‡ 2000 units per pound.
§ Must supply the following amounts of each vitamin per pound of mash:

Vitamin A	4000 units.
Vitamin D_3	600 units.
Riboflavin	2 mg.
Pantothenic acid	3 mg.
Niacin	9 mg.
Vitamin B_{12}	1.5 μg.

IOWA. (Iowa State College, Poultry Department, 1954.)

IOWA RATIONS FOR LAYING AND BREEDING HENS

Ingredient and Protein Content	15%	20%	26%
Ground yellow corn	1120	573	134
Ground whole oats	200	200	200
Wheat bran	100	200	200
Wheat middlings	100	200	200
Dehydrated alfalfa meal (17%)	100	200	300
Soybean oil meal (44%)	200	400	600
Meat and bone scrap (50%)	100	100	150
Steamed bonemeal (or equivalent)	40	60	100
Ground oystershell or limestone	20	30	55
Iodized salt	9	18.5	28
Manganese sulfate	1	1.5	2
Vitamin D concentrate (1500 I.C.U. per gr.)	1 lb.	2 lb	3 lb.
Riboflavin concentrate (227 mg./lb.)	6 lb.	10 lb.	20 lb.
Niacin (grams)	5 gm.	10 gm.	20 gm.
Vitamin B_{12} (milligrams)*	2 mg	3 mg.	4 mg.
Vitamin A concentrate (2250 I.U. per gr.)	3 lb.	5 lb.	8 lb.
Total pounds	2000	2000	2000

Note: The 15 per cent laying mash is to be fed as "all-mash." Grain is to be fed with the other mashes. Vitamins are usually provided in the form of concentrates. Adjustments must be made to compensate for differences in potency If the laying mashes are to be used as breeder rations, 40-100 pounds of fish solubles should be added per ton.

* Vitamin B_{12} to be added to laying rations if they are to be used as breeder rations

NEW ENGLAND COLLEGE CONFERENCE, JUNE, 1954.

RATIONS FOR LAYERS

	Mash and Grain	All-Mash
Feeding ratio; mash to scratch .	2/1	...
Mash ingredient	lb.	lb.
Ground yellow corn (1)	950	1125
Ground barley or pulverized oats (2)	100	100
Standard wheat middlings	200	200
Soybean oil meal (44%)	350	250
Fish meal (60%) (3)	40	25
Meat and bone scrap (50%)	75	50
Alfalfa meal (17%; 100,000 A/lb.)	100	75
Distillers' dried solubles (4) (5)	75	50
Dicalcium phosphate or equivalent (6)	40	32
Ground limestone (feeding grade)	65	75
Iodized salt	15	10
Dry vitamin D (1500 D/gm.) (7)	1.5	1
Manganese sulfate or equivalent (8)	0.4	0.25
Vitamin B_{12} supplement	(9)	(10)
Niacin	30 gm.	18 gm.
DPPD (diphenyl-p-phenylenediamine)	(11)	(11)
Totals (12)	2011.9	1993.25

(1) Two to four hundred pounds of coarsely ground wheat may be used to replace an equal amount of corn. Add 0.4 pounds of vitamin A and D oil for each 100 pounds of corn removed.

(2) On a nutrient content basis, barley is preferred to oats. Both barley and oats may be replaced by corn if a higher energy level is desired.

(3) If a high salt fish meal is used, omit the added salt.

(4) Twenty pounds of a butyl fermentation product containing at least 250 micrograms of riboflavin per gram (or 113.5 milligrams per pound) and 50 pounds of dried distillers' solubles; or 40 pounds yeast or 40 pounds of dried whey plus a riboflavin supplement to furnish not less than 2.0 milligrams per pound in the final ration. To determine the amount of riboflavin supplement to use above, divide the number of milligrams desired by the manufacturer's guaranteed potency. Example: Needed to furnish 454 milligrams using a product having a guaranteed potency of 113.5 milligrams per pound. Solution: 454 divided by 113.5 equals 4 pounds needed in addition to either the yeast or the solubles. This is an example only, not an actual case.

(5) A vitamin concentrate containing not less than 2 grams of riboflavin and 4 grams of pantothenic acid and possibly other vitamins may be used to replace part or all of the fermentation products, and the total weight may be made up by adding corn meal.

(6) Steamed bonemeal or defluorinated rock phosphate may replace the dicalcium phosphate on a phosphorus basis. Raw rock phosphate

containing not more than 3.5 per cent fluorine may replace one-quarter of the phosphorus in the dicalcium phosphate in the layer rations.

(7) Vitamin A and D feeding oil may be substituted on a unit basis.

(8) Manganese sulfate (70 per cent feeding grade) or equivalent amount of manganese from other sources.

(9) Use 9 milligrams of vitamin B_{12} per ton of ration.

(10) Use a vitamin B_{12} concentrate contributing not less than 6 mg. of vitamin B_{12} per ton of ration.

(11) DPPD (diphenyl-p-phenylenediamine) is an antioxidant and may be added at the 0.0125 per cent level (one-quarter pound per ton) to help prevent the destruction of the fat soluble vitamins.

(12) If an even 2000 pounds is desired, adjust by removing or adding middlings.

NEW YORK EGG-LAYING TESTS, 1952-1953. This is an all-mash formula. No supplements need to be fed, though water may be sprinkled on the mash as a feeding stimulus.

	Lb.
Yellow corn meal	945
Ground wheat	500
Alfalfa meal (17%)	40
Soybean meal (44%)	250
Fish meal	50
Meat scraps (50%)	50
Distillers' dried solubles	50
Dried whey	50
Dicalcium phosphate	25
Ground limestone	30
Salt	10
Manganese sulfate	0.5
Vitamin A oil (4500/gm.)	1
Dry D (1500/gm.)	1
	2002.5

OHIO. (Ohio Poultry Rations, Ohio Ext. Bul. 343, 1954.)

Laying and Breeding Mash, 20 per cent protein. This mash is adequate in the vitamins essential to good hatchability, therefore it can be fed to breeding flocks as well as market-egg flocks.

Keep the mash before the layers at all times. Feed whole grains (corn, wheat, or oats) at the rate of 40 pounds of grain to each 60 pounds of mash consumed. Another system is keep the mash before the birds all the time and limit the grain to from 2 to 6 quarts per 100 birds per day. Feed the smaller amount of grain when egg production is low.

Breeding Mash Concentrate, 26 per cent protein. Feed free choice as a laying and breeding mash for chickens and turkeys. *Grains such as corn, wheat, and oats also can be fed free* choice.

High-Energy Ration. This ration should be fed without the addition of any other feedstuff except a good source of calcium.

OHIO LAYING AND BREEDING RATIONS

Ingredients	Laying and Breeding Mash, 20% Protein lb.	Breeding Mash Concentrate, 26% Protein lb.	High-Energy Laying, Breeding, All-Mash lb.
Corn, yellow	400	292	600
Middling, standard or ground wheat	140	100	100
Wheat bran	70	...	...
Soybean oil meal (44% protein)	200	320	160
Meat scrap (50% protein)	50	50	25
Alfalfa, 17% protein dehydrated	50	75	40
Fish meal (58% protein) or fish solubles*	25	50	25
Rock phosphate, defluorinated or steamed bonemeal (15% phos.)	30	48	20
Iodized salt	10	15	5
Manganese sulfate	0.25	0.75	0.2
Dried whey (low lactose) or dried buttermilk*	25	50	25
	1,000	1,000	1,000
Additives per 1,000 lb. of mash			
Vitamin A, I.U.	2,000,000	3,000,000	500,000
Vitamin D_3, I.U.	1,000,000	1,350,000	500,000
Riboflavin, gm.	2.0	3.0	1.5
Calcium pantothenate, gm.	2.0	2.0	1.0
Vitamin B_{12}, mg.	6	12	6

* Preferred.

NORTH CAROLINA. (North Carolina State College of Agriculture and Engineering of the University of North Carolina, 1954.)

NORTH CAROLINA RATIONS FOR LAYERS

Ingredients	No. 46 All-Mash 16% lb.	No. 49 Grain-Mash 20% lb.
Ground yellow corn	925	870
Standard wheat middlings	300	50
Pulverized oats	250	100
Meat and bone scrap (50% protein)	50	75
Fish meal (60% protein)	25	50
Soybean oil meal (44% protein)	225	475
Alfalfa meal (17% protein) 100,000 A/lb.	75	100
Butyl fermentation solubles (250 micrograms riboflavin per gm.)	20	20
Steamed bonemeal or equivalent	50	120
Pulverized oystershells or equivalent	70	20
Salt	10	20
Feeding oil (300 D, 1500 A per gm.)	2	2
D-activated animal sterol (1500 D per gm)	1	2.25
Manganese sulfate	0.25	0.50
	gm	gm.
Niacin	18	20
	mg	mg.
Vitamin B_{12} supplement	3-6	6-12
Total	2003+	2004+

Suggestions on Feeding:

1. Do not feed a scratch mixture or separate grains with the all-mash, 16 per cent protein mash.
2. Feed a scratch mixture or separate grains with the 20 per cent protein mash.
3. Keep crushed oystershells or limestone before the birds that are fed the 20 per cent protein layer mash. It is not necessary to feed crushed oystershells or limestone to the chickens receiving the all-mash, 16 per cent protein mash.
4. The laying chicken fed a scratch mixture or separate grains should have access to insoluble hard grit or gravel. Crushed granite, quartz, and feldspar are examples of hard grit.

ONTARIO AGRICULTURAL COLLEGE. (S. J. Slinger, W. F. Pepper, and J. R. Cavers. O.A.C. Chicken Laying and Hatching Feed Formulas, O.A.C. Circular 142A, revised, January, 1954.)

Laying Mash No. 1. This is a conventional type laying mash containing about 20 per cent protein (N × 6.25). Laying mashes containing this level of protein have an advantage over those with 18 per cent protein or less in that they permit the use of more home-grown grain in relation to mash.

Laying Mash No. 2. This is a high-energy laying mash containing about 21 per cent protein (N × 6.25). The feed efficiency for egg production has been shown to be greater with high-energy diets such as this, than with conventional type laying mashes. There has recently been a growing interest in the use of high-energy diets for laying stock. A prime consideration in the use of such diets should be the relative cost and availability of the high-energy grains such as wheat and corn as compared with oats, barley, and mill feeds.

Laying Mash No. 3. This is an all-mash, high-energy ration containing about 16.5 per cent protein (N × 6.25). This mash should be freely accessible to the birds at all times, and no grain should be given. A free-choice supply of oystershell or other suitable calcium source should be available in separate hoppers at all times. The all-mash system of feeding is simpler than the mash-grain method since no error can be made in the proportions of mash and grain to be fed. The all-mash method also fills a need where automatic feeders are used.

Laying Concentrate. This concentrate may be mixed with ground grains to make laying mashes similar to numbers 1, 2, or 3. To make a conventional type laying mash such as No. 1, mix 100 parts of concentrate with 200 parts of ground grains. The ground grains in this case could be a mixture of 6 parts wheat, 3 of corn, 2 of barley, and 2 of oats by weight. This mixture will give a conventional-type laying mash containing about 20 per cent of protein. Mixing 100 parts of concentrate with 200 parts of ground wheat and corn will make a high-energy laying mash such as No. 2. If the proportions of wheat and corn are 9 to 4, the diet will contain about 20 per cent protein. If it is desired to make an all-mash, high-energy laying diet similar to No. 3, mix 100 parts of concentrate with 300 parts of ground wheat and 100 of ground corn.

Hatching Mash. If eggs are not wanted for hatching purposes immediately after the birds are housed, the birds may be maintained on laying mash until 6 weeks before eggs are desired for

setting. At this time they should be changed gradually to hatching mash and grain.

Hatching Concentrate. This concentrate when mixed with ground grains in the proportions of 100 parts of concentrate to 200 parts of ground grains will make a hatching mash containing about 20 per cent protein. Using ground grains in the ratio of 7 parts wheat, 3 of corn, 1 of barley, and 2 parts oats, by weight, will give a mash similar in composition to the hatching mash shown.

O.A.C. CHICKEN LAYING AND HATCHING FEED FORMULAS

Ingredients	Laying Mash No. 1 lb.	Laying Mash No 2 lb.	Laying Mash No. 3 lb.	Laying Concentrate lb.	Hatching Mash lb.	Hatching Concentrate lb.
Ground wheat	600	840	1100	...	685	...
Ground yellow corn	300	400	455	. .	300	...
Ground barley	180	.	. .		100	...
Pulverized oats	200	...	..		200	...
Dehydrated alfalfa meal or cereal grass	80	80	50	225	100	270
Meat meal (50% protein)	50	75	50	180	70	200
Fish meal (65% protein)	50	50	30	140	70	200
Dried buttermilk or skimmilk	50	50	30	140	60	160
Soybean oil meal (44% protein)	375	400	200	1000	310	870
Ground limestone	40	40	40	120	40	110
Steamed bonemeal or equivalent	55	45	35	140	45	130
Iodized salt	15	15	10	40	15	40
Vitamin A oil (10,000 I U /gm)	2	2	1	6	2 5	7
Dry vitamin D_3 (1,650 I.C.U / gm)	2	2	1	6	2 5	7
Manganese sulfate (feed grade)	0.5	0 5	0.25	1 5	0 5	1.5
	gm	gm	gm	gm.	gm.	gm.
Riboflavin	2	2	1	6	4	10
Antibiotic*	4-20	4-20	2-10	12-40	4-20	12-40
	mg.	mg.	mg	mg	mg	mg
Vitamin B_{12}	3	3	3	9	5	15
Calculated Analysis.	%	%	%	%	%	%
Minimum crude protein	20 1	20 9	16 6	35 5	20 2	35.8
Minimum crude fat	2 5	2 4	2 5	2 2	2 7	2 5
Maximum crude fiber	5 4	4 2	3 6	6 5	5 3	6 8
Calcium	2.0	2 0	1 7	5 6	2 0	5.5
Total phosphorus	0 9	0 9	0 7	1 9	0 9	2 0
Inorganic phosphorus	0 64	0 64	0 48	1 63	0 66	1 71

*If penicillin is the antibiotic being employed use the lower level, if aureomycin, terramycin, or bacitracin are used, the higher level should be added

Substitutions. An equal-parts mixture of wheat shorts and bran may be used to replace ground wheat in laying mash No. 1 or in the hatching mash.

Dried whey may replace dried buttermilk or skimmilk. For every 40 pounds of dried milk replaced by dried whey, increase the amount of soybean oil meal by 30 pounds and reduce the ground wheat by 30 pounds.

Vitamin A feeding oil and dry vitamin D_3 may be replaced by fish oil on an equal unitage basis. The vitamin A oil may be replaced by dry vitamin A or by vitamin A oils of other potency on an equal unitage basis.

Steamed bonemeal may be replaced by defluorinated rock phosphate. Other calcium and phosphorus carriers may also be used. Replacement should be based on the calcium and phosphorus content.

Manganese sulfate may be replaced by other manganese carriers to supply equal levels of manganese.

Ground limestone may be replaced by calcium carbonate.

WASHINGTON. (Washington Poultry Feed Formulas, Poultry Science Department, State College of Washington, Ext. Mimeo. 1107 and 1582, 1954.)

CHICKEN LAYER MASHES

Ingredients	1 %	2 %	3 %	4 %	5 %
Ground grains*	60.7	43.7	45.2	41.0	45.8
Wheat mixed feed (millrun)*	...	20.0	20.0	20.0	20.0
Fishmeal (70% protein)	4.0	...	5.0	1.5	...
Meat and bonemeal (50% protein)	...	5.0	5.0	...	10.0
Soybean oil meal (44% protein)	23.0	20.0	13.0	25.0	15.0
Dehydrated alfalfa or grass (carotene, 12 mg./100 gm.)	5.0	5.0	5.0	5.0	5.0
Limestone or shell flour	3.0	3.0	3.0	3.2	2.7
Steamed bonemeal or defluorinated phosphate	3.8	2.8	3.3	3.8	1.0
Salt (iodized, fine)	0.5	0.5	0.5	0.5	0.5
Add the following to each ton of feed					
Vitamin A, millions I.U.	2.0	2.0	2.0	2.0	2.0
Vitamin D_3, millions I.C.U.	1.2	1.2	1.2	1.2	1.2
Manganese sulfate, lb. (100% pure)	0.5	0.5	0.5	0.5	0.5

Suggested analysis: protein, 19.0 per cent; calcium, 2.5 per cent; phosphorus, 1.1 per cent; vitamin A, 5500 International units per pound; vitamin D_3, 560 International chick units per pound; riboflavin, 1.2 milligrams per pound.

The feeding of cracked or whole grains on the basis of the birds eating 60 per cent mash and 40 per cent grain is suggested. It is recommended that one third of the grain be fed in the morning and two thirds in the afternoon. All the grain may be fed at one time if more convenient, preferably in late afternoon. Shell or limestone grit should be available to the birds at all times. Granite or silica grit should be fed 1 day each week.

*Ground corn, milo, wheat, barley, or oats may be used singly or in any combination with 0 to 20 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 45 per cent in any mash. Barley may be used as the only cereal grain and in place of millrun if the feed is pelleted

WASHINGTON ALL INCLUSIVE LAYER AND BREEDER MASHES

Ingredients	1 %	2 %	3 %	4 %
Ground grains and millrun*	78.0	79.5	76.1	77.6
Fish meal (70% protein)	2.5	2.5	2.5	2.5
Meat and bonemeal	. . .	5.0	. . .	5.0
Soybean oil meal (44% protein)	12.0	7.0	12.0	7.0
Dehydrated alfalfa or grass (carotene, 12 mg./100 gm.)	3.0	3.0	3.0	3.0
Limestone or shell flour	1.7	1.3	3.6	3.2
Steamed bonemeal or defluorinated phosphate	2.3	1.2	2.3	1.2
Salt (iodized, fine)	0.5	0.5	0.5	0.5
Add the following to each ton of feed				
Vitamin A, millions I.U.	1.0	1.0	1.0	1.0
Vitamin D_3, millions I.C.U.	0.68	0.68	0.68	0.68
Riboflavin, gm.	1.5	1.5	1.5	1.5
Manganese sulfate, lb. (100% pure)	0.3	0.3	0.3	0.3

Suggested analysis: protein, 15 per cent; riboflavin, 1.7 milligrams per pound; vitamin A, 3300 I.U./lb.; vitamin D_3, 340 I.C.U./lb.; phosphorus, 0.8 per cent; calcium, mashes 1 and 2, 1.6 per cent; mashes 3 and 4, 2.25 per cent.

These diets are designed to be used as the only feed fed to the birds with the exception that a supplementary supply of calcium carbonate must be provided for laying or breeding hens fed layer and breeder mashes 1 and 2. This may be supplied in the form of hen-size oystershell or limestone. Layer and breeder mashes 3 and 4 contain all the calcium necessary for shell formation.

These layer and breeder diets may be fed with 1 or 2% whole grain, which is fed in the litter as an aid to keeping the litter stirred up.

*Ground corn, milo, wheat, barley, or oats may be used singly or in any combination with 0-10 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 25 per cent of the diet.

WISCONSIN. (University of Wisconsin, 1954.)

WISCONSIN LAYING MASHES

Ingredients	Laying Mash, lb.	26% Laying Supplement, lb.
Ground yellow corn	250	. . .
Wheat bran	100	100
Wheat middlings	100	200
Pulverized oats	150	. . .
Dehydrated alfalfa meal	100	200
Meat scrap	75	150
Soybean oil meal	175	250
Steamed bonemeal or defluorinated rock phosphate or equivalent	30	60
Iodized salt	10	20
400 D fish oil or powder*	6	12
Manganese sulfate (feeding grade)	1/4	1/2

Grains to be fed free choice with above rations.
Oystershell and granite grit fed free choice in all rations.

*Based on A O.A.C. units. If new International chick unit is used, 75 per cent of the above will be sufficient.

WISCONSIN ALL-MASH FEEDS FOR LAYING HENS PRODUCING MARKET EGGS

	%	%	%	%	%
Ground yellow corn	56.2	55.9	52.2	62.7	58.2
Ground oats or wheat	10.0	10.0	. . .	10.0	. . .
Wheat middlings	. . .	. . .	15.0	. . .	15.0
Alfalfa meal	5.0	5.0	5.0	5.0	5.0
Soybean oil meal	22.0	22.0	21.0	10.0	10.0
Meat meal	. . .	. . .	. . .	8.0	7.5
Steamed bonemeal or defluorinated superphosphate	3.0	. . .	3.0	1.0	0.5
Dicalcium phosphate	. . .	2.5	. . .	. . .	. . .
Pulverized limestone or oystershell	3.0	3.8	3.0	2.5	3.0
Salt	0.5	0.5	0.5	0.5	0.5
Vitamin A and D feeding oil (300 I.C.U. vitamin D, 1500 I.U. vitamin A per gm.)	0.3	0.3	0.3	0.3	0.3
Riboflavin (grams/100 lb.)	0.02	0.02	0.02	0.02	0.02
Manganese sulfate (grams/100 lb.)	5.0	5.0	5.0	5.0	5.0

The level of riboflavin supplement is indicated in grams of the pure vitamin per 100 pounds of feed because of the wide range of potencies of riboflavin supplements. Unfortified dried whey, a widely-used "natural" supplement, contains 0.013 gram of riboflavin per pound, and so would be used at 1.6 per cent of the mash to provide the level indicated in the table.

One to two per cent of stabilized animal fat could be used in any of these formulas in place of an equal quantity of corn and would have a beneficial effect on the texture of the feed.

Limestone or oystershell grit should be supplied to birds receiving these mashes.

SECTION III. RATIONS FOR BREEDERS

See also Appendix, Section II, since some rations are designated as laying and breeding rations.

CORNELL. (Department of Poultry Husbandry, New York State College of Agriculture, Stencil 205, January, 1953.)

Cornell Breeder Mashes. To be fed with approximately equal grain intake according to any good mash-and-grain program. Breeding ration should be fed for at least 4 weeks before eggs are taken for hatching.

Mixing Mashes. Mash concentrates to be used with local grain (see Section VII).

CORNELL BREEDER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Yellow corn meal	750	570	620	640
Ground wheat	300	200	...	...
Wheat flour middlings	...	...	300	200
Wheat standard middlings	...	200	...	150
Pulverized oats	100	200	200	...
Ground barley	...	...	...	200
Soybean meal	375	325	350	250
Corn gluten meal	...	50	...	...
Peanut meal	...	...	...	50
Fish meal	75	100	...	...
Fish solubles	...	...	75	...
Meat scrap	75	...	75	150
Corn distillers' dried solubles	50	...	100	75
Dried whey	50	100	50	75
Molasses distillers' solubles	...	25	...	...
Dehydrated alfalfa meal	100	100	100	100
Riboflavin supplement to supply (mg. riboflavin)	2300 mg.	1500 mg.	1000 mg.	1500 mg.
Vitamin B_{12} supplement to supply (mg. B_{12})	4 mg.	4 mg.	...	5 mg.
D-activated animal sterols (1500 I.C.U./gm.)	2	2	2	2
or				
Vitamin feeding oil (300 D, 1500 A)	10	10	10	10
Steamed bonemeal	75	90	90	70
Limestone	30	20	20	20
Salt (iodized)	20	20	20	20
Manganese sulfate (65% feeding grade)	0.5	0.5	0.5	0.5
Protein, %	20.7	20.5	20.6	20.5
Calcium, %	2.4	2.1	2.2	2.3
Total Phosphorus, %	1.2	1.2	1.2	1.2
Available, %	0.9	0.9	0.9	0.9
Vitamin A,* I.U./lb.	5800	5600	5600	5600
Vitamin D, I.C.U./lb.	680	680	680	680
Riboflavin, mg./lb.	2.7	2.6	2.5	2.6
Vitamin B_{12},† μg./lb.	4	4	3.2	3.6

* Assuming use of alfalfa meal containing 100,000 International units vitamin A activity and no vitamin feeding oil.

† From animal proteins and vitamin B_{12} supplement.

BRITISH COLUMBIA. (University of British Columbia and Department of Agriculture U.B.C. Feed Formulas for Poultry, 1954, Poultry Circ. 37.)

Hen Breeding Mash. To be fed with scratch grain in similar proportions as in the case of laying mash. To insure high hatchability, a distillers' feed product and/or liver meal should be included 30 days previous to collecting hatching eggs.

BRITISH COLUMBIA HEN-BREEDING MASH

Ingredients	lb per ton
Coarse ground wheat	720
Ground yellow corn	100
Pulverized oats	100
Ground barley	100
Wheat bran	100
Wheat middlings	100
Fish meal (65–70% protein)	100
Meat and bone scrap (50% protein)	100
Dried milk by-products	70
Soybean oil meal (44% protein)	200
Dehydrated green feed	100
Distillers' dried solubles or fermentation solubles	100
Ground limestone	50
Steamed bonemeal	30
Iodized salt	20
Manganese sulfate	8 oz.
Feeding oil (2250 I.U., A, 300 I C U , D per gram)	10
Riboflavin	4 gms.
Vitamin B_{12}	3 mg.
Recommended protein level	20%

NEW ENGLAND COLLEGE CONFERENCE, JUNE, 1954.

RATIONS FOR BREEDERS

	Mash and Grain	All-Mash
Feeding ratio; mash to scratch	2/1	. . .
Mash ingredient	lb.	lb.
Ground yellow corn (1)	975	1125
Ground barley or pulverized oats (2)	100	100
Standard wheat middlings	200	200
Soybean oil meal (44%)	250	175
Fish meal (60%) (3)	100	75
Meat and bone scrap (50%)	75	50
Alfalfa meal (17%; 100,000 A/lb.)	100	75
Distillers' dried solubles (4) (5)	75	50
Butyl fermentation products (4) (5)	25	25
Dicalcium phosphate or equivalent (6)	24	32
Ground limestone (feeding grade)	65	75
Iodized salt	15	10
Dry vitamin D (1500 D/gm.) (7)	1.5	1.0
Manganese sulfate or equivalent (8)	0.4	0.25
Vitamin B_{12} supplement	(9)	(10)
Niacin	30 gm.	18 gm.
DPPD (Diphenyl-p-phenylenediamine)	(11)	(11)
Totals (12)	2005.9	1993.25

(1) Two to four hundred pounds of coarsely ground wheat may be used to replace an equal amount of corn. Add 0.4 pound of vitamin A and D oil for each 100 pounds of corn removed.

(2) On a nutrient content basis, barley is preferred to oats. Both barley and oats may be replaced by corn if a higher energy level is desired.

(3) If a high salt fish meal is used, omit the added salt.

(4) Twenty pounds of a butyl fermentation product containing at least 250 micrograms of riboflavin per gram (or 113.5 milligrams per pound) and 50 pounds of dried distillers' solubles, or 40 pounds yeast or 40 pounds of dried whey plus a riboflavin supplement to furnish not less than 2.0 milligrams per pound in the final ration. To determine the amount of riboflavin supplement to use above, divide the number of milligrams desired by the manufacturer's guaranteed potency. Example: Needed to furnish 454 milligrams using a product having a guaranteed potency of 113.5 milligrams per pound. Solution: 454 divided by 113.5 equals 4 pounds needed in addition to either the yeast or the solubles. This is an example only, not an actual case.

(5) A vitamin concentrate containing not less than 2 grams of riboflavin and 4 grams of pantothenic acid and possibly other vitamins may be used to replace part or all of the fermentation products, and the total weight may be made up by adding corn meal.

(6) Steamed bonemeal or defluorinated rock phosphate may replace

the dicalcium phosphate on a phosphorus basis. Raw rock phosphate containing not more than 3.5 per cent fluorine may replace one-quarter of the phosphorus in the dicalcium phosphate in the rations.

(7) Vitamin A and D feeding oil may be substituted on a unit basis.

(8) Manganese sulfate (70% feeding grade) or equivalent amount of manganese from other sources.

(9) Use 9 milligrams of vitamin B_{12} per ton of ration.

(10) Use a vitamin B_{12} concentrate contributing not less than 6 milligrams of vitamin B_{12} per ton of ration.

(11) DPPD (diphenyl-p-phenylenediamine) is an antioxidant and may be added at the 0.0125 per cent level (one-quarter pound per ton) to help prevent the destruction of the fat soluble vitamins.

(12) If an even 2000 pounds is desired, adjust by removing or adding middlings.

NORTH CAROLINA. (North Carolina State College of Agriculture and Engineering of the University of North Carolina, 1954.)

NORTH CAROLINA RATIONS FOR BREEDERS

Ingredients	No 47 All-Mash 16%* lb.	No. 50 Grain-Mash 20%† lb.
Ground yellow corn	945	850
Standard wheat middlings	250	200
Pulverized oats	250	100
Meat and bone scrap (50% protein)	25	75
Fish meal (60% protein)	75	100
Soybean oil meal (44% protein)	200	375
Alfalfa meal (17% protein) 100,000 A/lb.	75	100
Whey, dried	20	20
Butyl fermentation solubles (250 micrograms riboflavin per gram)	30	40
Steamed bonemeal or equivalent	50	100
Pulverized oystershells or equivalent	70	20
Salt	10	20
Feeding oil (300 D, 1500 A per gram)	2	2
D-activated animal sterol (1500 D per gram)	1	2.25
Manganese sulfate	0.25	0.50
	grams	grams
Niacin	20	20
	milligrams	milligrams
Vitamin B_{12} supplement	6	12
Total	2003+	2004+

* Do not feed a scratch mixture or separate grains with the all-mash, 16 per cent protein mash.

† Feed a scratch mixture or separate grains with the 20 per cent protein mash. Keep crushed oystershells or limestone before the birds that are fed the 20 per cent breeder mash

TEXAS. (Agricultural and Mechanical College of Texas, 1954.)

TEXAS ALL-MASH BREEDER-LAYER RATION

Ingredients	lb./ton
Soybean oil meal (44% protein)	350
Fish meal	80
Dried whey	50
Dehydrated alfalfa leaf meal	80
Ground yellow corn	650*
Ground milo	650*
Bonemeal or defluorinated phosphate	40
Oystershell flour or calcium carbonate	40
Salt	10
Vitamin and mineral mixture†	50
Total	2000

*Milo and corn may be used interchangeably, depending on price and availability.

† Vitamin and mineral mixture in soybean oil meal:

Riboflavin	4 gm.
Calcium pantothenate	10 gm.
Niacin	25 gm.
B_{12}	6 mg.
Antibiotic	‡
Vitamin A (stable, dry A)	2,270,000 I.U.
Vitamin D_3 (stable, dry D)	1,200,000 I.C.U.
Manganese sulfate	227 gm.
Soybean oil meal	Enough to make total equal to 50 lb.

‡ Use 10 grams aureomycin, 10 grams bacitracin, 10 grams of terramycin or 4 grams penicillin. A combination of two, three, or four of the antibiotics may be used. If a combination is used, take a proportionate part of the above levels on a per ton basis.

WASHINGTON. (Washington Poultry Feed Formulas, Poultry Science Department, State College of Washington, Ext. Mimeo. 1183, 1954.)

CHICKEN BREEDER MASHES

Ingredients	1 %	2 %	3 %	4 %	5 %	6 %
Ground corn or ground milo	...	...	...	...	...	62.9
Ground grains*	45.2	42.9	46.9	38.8	40.8	...
Wheat mixed feed (millrun)*	20.0	20.0	20.0	20.0	20 0	...
Fishmeal (70% protein)	5.0	2.0	3.5	...	..	5.0
Meat and bonemeal (50% protein)	...	...	5.0	5.0	...	...
Soybean oil meal (44% protein)	13.0	18.0	9.2	13.0	21 8	20.0
Dehydrated alfalfa or grass (carotene, 12mg./100 gm.)†	10.0	10.0	10.0	10.0	10.0	5.0
Dried whey	...	...	...	2.5	...	...
Distillers' dried solubles	...	...	..	5.0	...	...
Limestone or shell flour	2.7	2.6	2.3	2.6	2.8	2.2
Steamed bonemeal or defluorinated phosphate	3.6	4.0	2.6	2 6	4.1	4.4
Salt (iodized, fine)	0.5	0 5	0.5	0.5	0.5	0 5
Add the following to each ton of feed						
Vitamin A, millions I.U.	..	..	..	...	...	1.9
Vitamin D_3, millions I.C.U.	1.2	1 2	1.2	1.2	1.2	1.2
Riboflavin (gm.)	2.1	2.2	2.0	1.1	2.2	2.8
Vitamin B_{12} (mg.)	...	6.0	...	8.0	11.0	...
Manganese sulfate, lb. (100% pure)	0.5	0 5	0.5	0.5	0.5	0.5

Suggested analysis: Protein, 19 per cent; calcium, 2 5 per cent; phosphorus, 1.1 per cent; vitamin A, 5500 International units per pound; vitamin D_3, 600 International chick units per pound; riboflavin, 2 8 milligrams per pound.

These mashes are formulated for hand feeding of grain on the basis of the birds eating 60 per cent mash, pellets, or crumbles and 40 per cent cracked or whole grains It is recommended that one third of the grain be fed in the morning and two thirds in the afternoon All the grain may be fed at one time if more convenient, preferably in late afternoon. Supplemental calcium in the form of limestone grit or shell should always be available in separate hoppers Granite or silica grit should be fed one day each week

*Ground corn, milo, wheat, barley, or oats may be used singly or in any combination with 0 to 20 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 45 per cent of the mash.

†Dehydrated alfalfa or grass may be reduced to 5 per cent and the ground grain increased by 5 per cent if 1,916,000 International units of vitamin A are added per ton of mash. Vitamin A supplement will not be required if a dehydrated alfalfa or grass assaying 15 milligrams per 100 grams or more of carotene is used.

WISCONSIN. (University of Wisconsin, 1954.)

WISCONSIN BREEDER MASHES

Ingredients	No. 1	No. 2
Ground yellow corn	300	325
Wheat bran	100	100
Wheat middlings	100	100
Pulverized oats	100	100
Dehydrated alfalfa meal	100	100
Meat scrap	50	40
Fish meal	. . .	40
Soybean oil meal	200	160
Steamed bonemeal or defluorinated rock phosphate or equivalent	30	20
Iodized salt	10	10
Riboflavin*	Yes	Yes
Vitamin B_{12} supplement†,‡	Yes	No
400 D fish oil or powder§	6	6
Manganese sulfate (feeding grade)	1/4	1/4

Grains to be fed free choice with above rations.
Oystershell and granite grit fed free choice in all rations.

* Riboflavin, 1.0 milligram per pound of feed from any source.

† Use according to manufacturer's directions.

‡ Some commercial supplements do not meet the minimum standards for this product, but they may be good sources.

§ Based on A.O.A.C. units. If new International chick unit is used, 75 per cent of the above will be sufficient.

SECTION IV. FATTENING RATIONS

CORNELL. (G. F. Heuser, Poultry rations, Cornell Bul. 45, revised, 1941.)

CORNELL FATTENING RATIONS

	To Be Fed with Liquid Milk*	To Be Fed without Liquid Milk†
Corn meal	50	50
Wheat flour middlings	20	20
Ground heavy oats	10	10
Dried buttermilk or skimmilk		10
Meat scrap		10

*Mixed to a batter, fresh at each feeding, with buttermilk or skimmilk. Will require approximately 2 pounds (1 quart) of milk to 1 pound (1 quart) of mash.

†Mixed to a batter, fresh at each feeding, with water. Will require approximately 3 pounds (1 1/2 quarts) of water to 2 pounds (2 quarts) of mash.

BRITISH COLUMBIA. (University of British Columbia and Department of Agriculture U.B.C. Feed Formulas for Poultry, 1954. Poultry Circ. 37.)

Fattening Mash. All-mash ration to be fed moistened with water or liquid skimmilk. The feeding oil should be discontinued 1 to 2 weeks before marketing the birds. If yellow corn is expensive, it may be replaced with other grains. When available and not too expensive, 3 to 5 per cent of corn oil or soybean oil may be fed to advantage during the last 10 days of fattening.

BRITISH COLUMBIA FATTENING MASH

Ingredients	lb. per ton
Coarse ground wheat	650
Ground yellow corn	600
Pulverized oats	200
Ground barley	100
Wheat middlings	100
Meat and bone scrap (50% protein)	50
Dried milk by-products	50
Soybean oil meal (44% protein)	150
Dehydrated green feed	50
Ground limestone	25
Steamed bonemeal	10
Iodized salt	10
Manganese sulfate	4 oz.
Feeding oil (2250 I.U., A; 300 I.C.U., D per gram)	5
Riboflavin	2 gm.
Recommended protein level	14%

CALIFORNIA. (H. J. Almquist, T. H. Jukes, and W. E. Newlon, Feeding chickens, Calif. Circ. 108, revised, 1940.)

	Pounds
Ground yellow corn	100
Ground whole barley	100
Ground oat groats or oatmeal	50
Dried skimmilk	50
Water to mix to the consistency of a thick soup	

KANSAS. (Poultry rations, Kans. Agr. Exp. Sta., Dept. Poultry, C Form 1, Oct., 1943.)

Crate Feeding

	Pounds
Corn meal	60
Oatmeal or shorts	40
Buttermilk	200

When liquid milk is not available, add 40 pounds of condensed milk to 100 pounds of grain and enough water to give the consistency of thick cream.

Pen or Lot Feeding

	Pounds
Shelled corn, kafir or milo	85
Semi-solid or condensed buttermilk	15

This ration should be fed in hoppers 4 to 6 weeks. The milk paste is added to the grain once daily at the rate of 3 to 3½ pounds for 100 chickens and 5 to 6 pounds daily per 100 turkeys.

MACDONALD COLLEGE, CANADA. (Macdonald College fattening rations. Canadian Poultry Review, Sept., 1940.)

MACDONALD COLLEGE FATTENING RATIONS

Feed	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.	7 lb.
Ground yellow corn	22.75	22.50	30.00	23.25	31.00	16.00	. . .
Ground wheat	22.75	22.50	. . .	23.25	. . .	. . .	. . .
Ground oats	22.75	22.50	30.00	23.25	31.00	30.00	31.00
Ground barley	22.75	22.50	30.00	23.25	. . .	30.00	31.00
Ground buckwheat	. . .	. . .	. . .	. . .	30.00	. . .	31.00
Rice feed*	. . .	. . .	. . .	. . .	. . .	16.00	. . .
Beef meal	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Powdered milk	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Crude corn oil	2.00	2.00	2.00	. . .	. . .	. . .	. . .
Bone char or charcoal	. . .	1.00	1.00	. . .	1.00	1.00	. . .
Salt	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*Ground broken rice and polishings.

The following suggestions are offered concerning the purpose for which each of the foregoing rations is intended:

1. For commercial feeding on short periods—4 to 8 days—any class of stock.
2. For commercial feeding where white skin and fat finish are desired. Add 1 per cent bone char or English nut charcoal to the ration.
3. For pen feeding or range finishing of broilers. Dry mash fed ad libitum in hoppers and two wet-mash feedings per day, giving as much as will be cleaned up readily.
4. For farm fattening (confinement in crates or pen feeding) 14-day feeding period.
5. Recommended for heavy roasters and fowl where yellow fat and skin are not objectionable.
6. Where rice feed is available, this ration should give excellent results with any class of stock.
7. For heavy stock, such as roasters and fowl especially. Will produce a white finish.

ONTARIO AGRICULTURAL COLLEGE. (S. J. Slinger, W. F. Pepper, and J. R. Cavers. O.A.C. Chicken Starting, Growing, and Fattening Formulas, O.A.C. Circular 142, revised, Jan., 1954.)

Roaster Fattening Mash. This mash contains about 14 per cent protein (N × 6.25). It is designed to aid in the fattening of mature or relatively mature stock and is not recommended for fattening broilers. It is fed without grain in the form of a thin gruel or "pour batter" made by mixing with water or liquid skimmilk or buttermilk. For fattening roasters or fowl, it is recommended that the birds be given the amount they will just clean up in 15 minutes, three times daily, for a period of 10 to 12 days. Water should be available at all times to birds being fattened.

O.A.C. FATTENING MASH

Ingredient	lb.
Ground wheat	750
Ground yellow corn	600
Ground barley	100
Pulverized oats	278
Dehydrated alfalfa meal (100,000 I.U. vitamin A activity/lb. or cereal grass)	20
Meat meal (50% protein)	50
Dried buttermilk or skimmilk	50
Soybean oil meal (44% protein)	100
Ground limestone	20
Steamed bonemeal or equivalent	20
Iodized salt	10
Vitamin A oil (10,000 I.U./gm.)	0.75
Dry vitamin D_3 (1,650 I.C.U./gm.)	1
Manganese sulfate (feed grade)	0.25
	gm.
Riboflavin	1
Antibiotic*	2–10
	mg.
Vitamin B_{12}	3
Calculated analysis:	%
Minimum crude protein	14.1
Minimum crude fat	3.0
Minimum crude fiber	4.5
Calcium	1.0
Total phosphorus	0.6
Inorganic phosphorus	0.35

*If penicillin is the antibiotic, use the lower level. If aureomycin, terramycin, or bacitracin are used, the higher level should be employed.

Substitution. Wheat middlings can replace ground wheat.

SECTION V. RATIONS FOR TURKEYS

CORNELL. (Turkey rations, New York State College of Agr. Dept. of Poultry Husbandry, Stencil 208, revised, July, 1953.)

Starting Mash. The starting mash is kept available at all times as an all-mash ration to 4 or 8 weeks of age.

Growing Mashes. The growing mash to be fed during the 4- to 8-week period should be fed as an all-mash ration. After 8 weeks of age both grain and mash are fed. Scratch grains may be fed free choice after 12 weeks. It also would be advisable to feed extra oystershell or some other source of calcium. When turkeys are to be marketed as turkey broilers, the fish meal should be replaced by high quality meat scrap in order to prevent "fishy flavor" in the broilers. If the turkeys are to be reared in confinement or if the available range is not in good condition, care must be taken to supply adequate amounts of vitamin A.

Breeding Mash. The breeding mash recommendations are designed for a grain-and-mash feeding system. The grain intake should constitute at least half but should not exceed 2/3 the total daily feed consumption. Free-choice oystershell or other calcium supplement should be provided.

CORNELL TURKEY STARTING RATION

Feed as all-mash ration to 4 or 8 weeks of age

Ingredients	lb./ton
Corn, ground yellow	588
Wheat flour middling	300
Oats, pulverized	100
Soybean meal, solvent, 44% protein	580
Fish meal	100
Meat and bone scrap	150
Dried skimmilk, or dried whey product*	60
Dried brewers' yeast	40
Alfalfa meal, 17% protein	40
Ground limestone	30
Salt, iodized	10
Manganese sulfate, feed grade, 70% $MnSO_4$	0.5
Choline chloride, 70% solution, to supply	1.5
Niacin supplement, to supply	40 gm./ton
Mixed-tocopheryl acetate supplement, to supply	5 gm./ton
Vitamin A supplement to supply	3000 units/lb.
D-activated animal sterol supplement to supply	600 units/lb.
Riboflavin supplement, to supply	0.5 mg./lb.
Antibiotic feed supplement, to supply	10 gm./ton

Approximate analyses:

Protein, %	28
Fat, %	3.6†
Fiber, %	4.3
Calcium, %	1.9
Phosphorus, %	0.9
Riboflavin, mg./lb.	2.3
Niacin, mg./lb.	42
Choline, mg./lb.	1028
Pantothenic acid, mg./lb.	5.7
Vitamin A, units/lb.	5690
Vitamin D, units/lb.	600

* Dried whey product containing approximately 50 per cent or less lactose; dried whey containing more lactose is less effective, probably because it is not well tolerated.

† Fat value depends upon fat content of animal protein supplements. If these supplements have been solvent-extracted, the fat value will be somewhat lower.

CORNELL TURKEY GROWING MASHES

Ingredient	Growing Mash 4-8 Weeks (All Mash) lb./ton		Growing Mash after 8 Weeks (with Grain)* lb./ton	
Corn meal, yellow	628.5		669.5	
Wheat middlings	300	(flour)	400	(standard)
Oats, pulverized	200		200	
Soybean meal, solvent, 44% protein	400		200	
Fish meal	100*		. . .	
Meat and bone scrap	100		200	
Dried brewers' yeast	40		40	
Dried whey product or dried skim-milk	60		60	
Alfalfa meal, 17% protein	100†		140†	
Ground limestone	30		30	
Steamed bonemeal or dicalcium phosphate	30		40	
Salt, iodized	10		20	
Manganese sulfate, feed grade, 70% $MnSO_4$	0.5		0.5	
Choline chloride, 70% solution to supply	1		. . .	
Riboflavin supplement to supply	0.5	mg./lb.	2.0	mg./lb.
Niacin supplement to supply	40	gm./ton	40	gm./ton
Mixed-tocopheryl acetate supplement	5	gm./ton	5	gm./ton
Vitamin A supplement to supply	5000	units/lb.	1000	units/lb.
D-activated animal sterol supplement	600	units/lb.	1200	units/lb.
Antibiotic feed supplement to supply	10	gm /ton	10	gm./ton

Approximate analyses

Protein, %	24 6	20.0
Fat, %	3 7	4.2
Fiber, %	5 1	5.7
Calcium, %	1.9	2.3
Phosphorus, %	1 0	1.1
Riboflavin, mg./lb.	2.3	3.8
Choline, mg /lb.	822	740
Pantothenic acid, mg./lb.	6	7
Vitamin A, units/lb.	5750	8740
Vitamin D, units/lb.	600	1200

* Fish meal should be replaced by meat scrap if turkeys are to be marketed early as broilers so as to prevent "fishy flavor."

† Formula calculations based on alfalfa containing 100,000 units of vitamin A activity per pound If lower-potency alfalfa is used, the required vitamin A level should be maintained by additional high-potency vitamin A supplement.

CORNELL TURKEY BREEDING MASH

Ingredients	Breeding Mash (Fed with Grain) lb. per Ton
Corn meal, yellow	404.5
Wheat standard middlings	400
Oats, pulverized	200
Soybean meal, solvent, 44% protein	240
Fish meal	100
Meat and bone scrap	200
Dried skimmilk or dried whey product	100
Distillers' dried solubles	100
Alfalfa meal, 17% protein	150*
Dicalcium phosphate or steamed bonemeal	60
Ground limestone	25
Salt, iodized	20
Manganese sulfate, feed grade, 70% $MnSO_4$	0.5
Riboflavin supplement, to supply	3.5 mg./lb.
Mixed-tocopheryl acetate supplement to supply	5 gm./ton
Vitamin A supplement to supply	5000 units/lb.
D-activated animal sterol supplement to supply	1800 units/lb.

Approximate analyses

Protein, %	24
Fat, %	4.6
Fiber, %	5.8
Calcium	2.8
Phosphorus	1.4
Riboflavin, mg./lb.	6.1
Choline, mg./lb.	686
Pantothenic acid, mg./lb.	6.3
Vitamin A, units/lb.	12,950
Vitamin D, units/lb.	1,800

* Formula calculations based on alfalfa containing 100,000 units of vitamin A activity per pound. If lower potency alfalfa is used, the required vitamin A level should be maintained by additional high-potency vitamin A supplement.

CALIFORNIA. (V. S. Asmundson and F. H. Kratzer, Turkey Production in California, Calif. Circ. 110, 1951.)

Poult Starting Mashes. Poults should be started on an all-mash ration. Slightly more rapid early growth may be produced by feeding the high-energy mash. The poults may be fed this ration for the first 2 to 4 weeks and then changed to the regular starter.

Poultry Growing and Developing Rations. After poults are 6 weeks old they are fed some grain. The grain should be started very gradually, because sudden changes in the ration will slow up growth. A little grain may be scattered on top of the mash in the afternoon at first. A suitable growing ration for poults that are running outside may consist of any starting mash with the fish oil omitted or of the growing, or high-protein, mashes with whole grains added.

Developing and Finishing Rations. The developing and finishing ration may consist of the growing mash fed with whole grains or of a high-protein mash fed with large amounts of scratch grains.

Feeding Breeder Hens. During the cloudy months, some vitamin D should be included in the mash. The mash should be fed with equal parts of scratch grain. Fresh greens may be fed when available; and, if they are abundant, the alfalfa meal may be reduced to 200 pounds and the ground grains increased to 1000 pounds. Additional calcium may be furnished by placing cracked oystershell or limestone before the birds.

CALIFORNIA POULT STARTER MASHES

Feedstuff	Regular 1 lb.	Regular 2 lb.	Regular 3 lb.	Regular 4 lb.	High-Energy lb.
Fish meal	200	140	150	100	293
Meat scrap	...	140	50	100	100
Soybean oil meal	500	450	500	525	500
Liver meal	...	...	...	...	40
Molasses	...	...	...	...	50
Alfalfa meal*	100	100	100	100	100
Wheat bran	200	200	200	200	...
Ground wheat	200	200	200	200	200
Ground barley	265	270	270	255	...
Ground corn	400	400	400	400	600
Bonemeal, special steamed†	25	0	30	20	10
Ground limestone	50	40	40	40	30
Salt, iodized	10	10	10	10	10
Manganese sulfate	1/2	1/2	1/2	1/2	1/2
Dried whey	40	40	40	40	50
Fish oil (2250 A, 300 D)‡	3	3	3	3	3
Vitamin D carrier (1500 D/gm.)	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
Riboflavin supplement§	5	5	5	5	7
Choline chloride	1	1	1	1	...
Antibiotic supplement	+	+	+	+	+

* Should contain carotene equivalent to at least 67,000 International units of vitamin A per pound.

† Other products of equivalent calcium and phosphorus content may be used.

‡ Proportionate amounts of products of other potency may be used.

§ Containing 225 milligrams of riboflavin per pound. A proportionate amount of a product of different potency may be used.

CALIFORNIA TURKEY GROWING MASHES (20 per cent protein)

Feedstuff	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.
Fish meal	100	...	50	100	...
Meat scrap	...	100	...	...	100
Soybean oil meal*	400	400	450	400	400
Alfalfa meal†	200	200	200	300	300
Wheat bran	300	300	300	300	300
Ground grains	897	907	849	779	789
Molasses	...	...	...	20	20
Bonemeal, special steamed‡	40	30	40	40	30
Ground limestone	40	40	40	40	40
Salt, iodized	20	20	20	20	20
Manganese sulfate	1/2	1/2	1/2	1/2	1/2
Dried whey	...	...	50	...	...
Vitamin D carrier (1,500 D/gm.)	1	1	1	1	1
Riboflavin§	2	2	...	...	...

* Soybean oil meal may be partly replaced by cottonseed meal, 10 per cent (200 pounds); or sesame seed oil meal, 5 per cent (100 pounds).

† Should contain carotene equivalent to at least 67,000 International units of vitamin A per pound.

‡ Other products of equivalent calcium and phosphorus content may be used.

§ Containing 225 milligrams of riboflavin per pound. A proportionate amount of a product of different potency may be used.

CALIFORNIA CONCENTRATE TURKEY GROWING MASHES
(30 per cent protein)

Feedstuff	1 lb.	2 lb.	3 lb.
Fish meal	200	100	200
Meat scrap	...	100	...
Soybean oil meal*	800	800	800
Alfalfa meal†	400	500	500
Wheat bran	300	250	250
Ground grains	94	68	...
Molasses	...	...	50
Bonemeal, special steamed‡	80	60	80
Ground limestone	80	80	80
Salt, iodized	40	40	40
Manganese sulfate	3/4	3/4	3/4
Vitamin D carrier (1,500 D/gm.)§	2	2	2
Riboflavin supplement‖	4	...	...

* Soybean oil meal may be partly replaced by cottonseed meal, 20 per cent (400 pounds); or sesame seed oil meal, 10 per cent (200 pounds).

† Should contain carotene equivalent to at least 67,000 International units of vitamin A per pound.

‡ Other products of equivalent calcium and phosphorus content may be used.

§ Proportionate amounts of products of different potency may be used.

‖ Containing 225 milligrams per pound. A proportionate amount of a product of different potency may be used.

CALIFORNIA TURKEY BREEDER MASHES

Feedstuff	1 lb.	2 lb.	3 lb.	4 lb.
Fish meal	100	200	50	100
Meat scrap	100	...	150	...
Soybean oil meal	200	200	250	350
Alfalfa meal*	300	300	300	300
Wheat bran or millrun	300	300	300	300
Ground grains	805	843	813	773
Bonemeal, special steamed†	20	30	10	50
Ground limestone	40	40	40	40
Salt, iodized	20	20	20	20
Manganese sulfate	1/2	1/2	1/2	1/2
Dried whey	100	50	50	50
Vitamin A and D feeding oil (2,250 A, 300 D/gm.)‡	6	6	6	6
Vitamin D source (1,500 D/gm.)‡	3	3	3	3
Riboflavin source§	6	8	8	8

* Should contain carotene equivalent to at least 67,000 International units of vitamin A per pound..

† Other products of equivalent calcium and phosphorus content may be used.

‡ Proportionate amounts of products of other potency may be used.

§ Containing 225 milligrams of riboflavin per pound. A proportionate amount of a product of different potency may be used.

IOWA. (Iowa State College Poultry Department, 1954.)

IOWA STARTING RATIONS FOR TURKEY POULTS

Ingredients	1	2	3	4
Ground yellow corn	544	648	465	529
Ground oats	100	100	100	100
Wheat bran	200	100	100	100
Wheat midds	200	200	200	100
Dehydrated alfalfa meal	100	100	100	100
Soybean oil meal (44%)	450	400	600	600
Meat and bone scrap (50%)	100	150	150	200
Fish meal (65%)	100	50	100	50
Fish solubles	...	50	...	50
Dried buttermilk	100	100	100	100
Steamed bonemeal (or equivalent)	25	30	20	...
Ground limestone or oystershell	40	30	25	30
Iodized salt	9.5	9.5	9.5	9.5
Manganese sulfate	0.5	0.5	0.5	0.5
Riboflavin concentrate (227 mg./lb.)	15.0	15.0	15.0	15.0
2250 A, 300 D concentrate	7	7	7	7
1500 D concentrate	2	2	2	2
Choline chloride (25%)	7	7	6	6
Niacin (100%)	20 gr.	20 gr.	20 gr.	20 gr.
Pantothenic acid	10 gr.	10 gr.	10 gr.	10 gr.
Methionine	...	1.0	...	1.0
Antibiotic*	+	+	+	+
Total pounds	2000	2000	2000	2000
Calculated analysis:				
Protein (minimum), %	24.0	24.0	28.0	28.0
Fat, %	3.9	4.1	3.8	3.9
Fiber, %	5.4	5.0	5.3	5.1
Calcium, %	2.1	2.1	2.0	2.0
Phosphorus, %	1.0	1.0	1.1	1.0

*Antibiotics may be used according to the manufacturer's recommendations with any of these rations. Vitamins are usually added as concentrates, and adjustments must be made to compensate for the variation in potency of these concentrates.

Methionine may be added at 1/2 to 1 pound per ton to any of these rations.

IOWA RATIONS FOR GROWING TURKEYS

Ingredients	1*	2	3	5	6*	7
Ground yellow corn	547	397	496	332	378	238
Ground whole oats	100	100	120	. . .	. . .	. . .
Wheat bran	100	100	100	100	100	100
Wheat middlings	100	100	100	100	100	100
Bonemeal or defluorinated phosphate	150	220	150	160	160	200
Ground limestone or oystershell	50	20	25	20	20	20
Iodized salt	18	18	18	18	18	18
Manganese sulfate	2	2	2	2	2	2
Dehydrated alfalfa meal (17% protein)	100	100	100	100	100	100
Fish meal (65% protein)	100	. . .	. . .	. . .	100	. . .
Condensed fish solubles (33% protein)	. . .	100	. .	. . .	. . .	100
Meat and bone scrap (50% protein)	150	100	200	225	175	125
Soybean meal (41-44% protein)	540	700	550	800	800	950
2250 A, 300 D concentrate (oil or dry)†	14	14	14	15	15	15
Vitamin D concentrate (1500 I.C.U. per gm.)†	5	5	5	6	6	6
Riboflavin concentrate (227 mg. per lb.)†	20	20	16	18	22	22
Dried milk	. . .	. . .	100	100	. . .	. . .
Choline chloride (25% or equivalent)†	4	4	4	4	4	4
Niacin	20 gr.	20 gr.	20 gr.	20 gr.	20 gr.	20 gr.
Pantothenic acid	6 gr.	6 gr.	6 gr.	6 gr.	6 gr.	6 gr.
Total pounds	2000	2000	2000	2000	2000	2000
Calculated analysis:						
Protein, %	24.1	24.0	23.7	28.1	28.6	28.3
Fat, %	2.4	2.2	2.6	2.2	2.1	1.7
Fiber, %	6.1	6.2	6.3	6.3	6.3	6.6
Calcium, %	4.3	4.2	3.9	4.2	4.0	4.1
Phosphorus, %	1.9	2.3	2.0	2.1	2.1	2.2

* Rations 1 and 6 preferred.

† Concentrates of these nutrients with different potencies may be used if adjustments are made to compensate for variation in potency. Antibiotics may be used according to manufacturers' recommendations as supplements to these rations. Mash and grain are to be available to the turkeys at all times.

NEBRASKA. (University of Nebraska Leaflet 109, 1953.)

NEBRASKA TURKEY RATIONS

Ingredient	Turkey Starter 53-T lb.	Turkey Grower 53-TG lb.
Ground yellow corn	340	247
Wheat shorts or pulverized oats	150	200
Whole oats	...	200
Soybean meal	250	150
Alfalfa meal (17% protein plus)	50	50
Meat scraps (50% protein plus)	100	100
Fish meal	20	20
Fish solubles blend	20	...
Dried whey	30	...
Nebraska Vitamin Concentrate No. 4 (or equivalent)*	10	3
Mineral Mix No. 57†	30	30
Total	1000	1000
Calculated protein level (per cent)	24.2	22.2

* Each pound of Vitamin Concentrate No. 4 to carry the following minimum values:

Riboflavin	0.2 gm.
Calcium pantothenate	0.4 gm.
Niacin	0.6 gm.
Choline chloride	2.0 gm.
D_3	135,000 I.C.U.
B_{12}	0.3 mg.
Antibiotic (procaine penicillin)	200 mg.
(aureomycin)	1 gm.
(terramycin)	1 gm.
(bacitracin)	1 gm.

†Mineral Premix Formula No. 57

	Parts by Weight
Limestone	403
Steamed bonemeal (or equivalent)	403
Salt	161
Trace Mix No. 1‡	33

‡Trace Mix No. 1 to carry enough manganese, iodine, iron, cobalt, copper, zinc, and other minor mineral elements when included at a level of 33 parts per 1000 and the complete mineral supplement is used at a level of either 2 or 3 per cent to supplement ingredients as called for in these formulas.

NORTH CAROLINA. (North Carolina State College of Agriculture and Engineering of the University of North Carolina, 1954.)

NORTH CAROLINA TURKEY MASHES

	No. 51 Starter 28% lb.	No. 52 Grower 28% lb.	No. 53 Breeder 20% lb.
Ground yellow corn	600	425	863
Wheat middlings	100	100	200
Pulverized oats	100	...	100
Meat and bone scraps (50% protein)	100	300	100
Fish meal (60% protein)	125	...	100
Soybean oil meal (44% protein)	750	700	300
Alfalfa meal (17% protein) 100,000 A per lb.	75	200	125
Whey, dried	50	75	75
Butyl fermentation solubles (500 micrograms riboflavin per gram)	30	30	30
Steamed bonemeal or equivalent	30	150	75
Pulverized oystershells or equivalent	40	...	...
Salt	10	25	20
Feeding oil (300 D, 1500 A per gram)	2.5	5	5
D-activated animal sterol (1500 D per gram)	1.75	5	3.5
Choline chloride (dry 25%)	3.0	2	2
Manganese sulfate	0.5	0.7	0.5
	grams	grams	grams
Niacin	60	60	55
Antibiotic supplement*	+	...	...
			milligrams
Vitamin B_{12} supplement	.	.	6-10
Total	2017+	2017+	1999+

* Aureomycin, bacitracin, penicillins, and terramycin are added to starter mashes for the purpose of stimulating growth in young turkeys. Two arsonic compounds are also being used commercially in starter mashes as growth stimulants. The quantity of antibiotic as well as arsonic compound added to a starter mash should be governed by the recommendations of the manufacturer.

Feeding Suggestions

1. Self-feed the starting mash without grains for 8 weeks.
2. After the eighth week begin self-feeding cracked yellow corn and whole oats in separate feed hoppers. Gradually replace the starting mash with growing mash. Complete the change by the end of the tenth week.
3. Feed the growing mash with grains until the turkeys are marketed.
4. Self-feed crushed oystershells or limestone to supply additional calcium to the growing and breeding turkeys.
5. The growing and breeding turkeys should have access to insoluble

ONTARIO AGRICULTURAL COLLEGE. (S. J. Slinger, W. F. Pepper, and J. R. Cavers, O.A.C. Turkey Feed Formulas, O.A.C. Circular 141, revised, January, 1954.)

Starter. This mash contains about 27 per cent protein (N × 6.25). It is made to be fed as an all-mash ration for the first 4 weeks. It will, however, give good results if fed with a free-choice supply of grain after 4 weeks and continuing to 8 weeks of age.

Grower Mash (4 to 8 weeks). This mash contains about 26 per cent protein (N × 6.25). As an alternative to using the starter plus grain from 4 to 8 weeks, this mash may be given as an all-mash ration.

Grower Mash (8 to 24 weeks). This mash contains about 20 per cent protein (N × 6.25). It should be fed with a free-choice supply of grain. This mash and the grower concentrate are formulated for confined birds. If used for birds on range, the dehydrated alfalfa and vitamin A and D concentrates may be reduced by one-half.

Grower Concentrate (8 to 24 weeks). This concentrate when mixed in the proportion of 100 pounds of concentrate to 200 pounds of ground grains—wheat, corn, oats, and barley—will contain about 19 per cent protein (N × 6.25). Greater efficiency of feed utilization will result from mixing the concentrate with ground grains than from feeding the concentrate as such and a free-choice supply of whole grains. The resultant 19 per cent protein mash should be fed with a free-choice supply of grain.

Breeder Mash. This mash contains about 20 per cent protein (N × 6.25). It should be fed in the proportion of 50 parts of mash to 50 parts of grain or 60 parts of mash to 40 parts of grain. The latter ratio is superior during the period of heaviest production. Oystershell or other suitable source of calcium should be freely accessible to the breeders when fed this ration.

Turkey Broiler Finishing Mash. This mash contains about 19 per cent protein (N × 6.25). It is designed as an all-mash ration for turkey broilers the last 6 weeks before marketing. The turkey starter mash (0 to 4 weeks) is satisfactory for the

O.A.C. TURKEY FEED FORMULAS

Ingredient	Turkey Starter Mash (0-4 wk.) lb.	Turkey Grower Mash (4-8 wk.) lb.	Turkey Grower Mash (8-24 wk.) lb.	Grower Concentrate (8-24 wk.) lb.	Turkey Breeder Mash lb.	Turkey Broiler Finishing Mash lb.
Ground wheat	500	500	640	...	600	900
Ground yellow corn	300	200	200	...	200	500
Pulverized oats	...	100	200	...	200	...
Ground barley	...	100	200	...	165	...
Dehydrated alfalfa meal (100,000 I.U. of vitamin A/lb.) or cereal grass	100	100	120	270	200	50
Fish meal (65% protein)	50	40	20	70	80	50
Meat meal (50% protein)	40	40	40	100	40	40
Dried buttermilk or skimmilk	40	40	40	100	70	40
Soybean oil meal (44% protein)	840	750	425	1200	300	320
Tallow or grease*	20	20	20	30	20	20
Ground limestone	30	30	30	70	50	30
Steamed bonemeal or equivalent	65	65	50	125	55	40
Iodized salt	10	10	10	25	15	5
Vitamin A oil (10,000 I.U./gm.)	1	1	1	3	2	1
Dry vitamin D_3 (1,650 I.C.U./gm.)	2	2	2	5	4	2
Manganese sulfate (feed grade)	0.3	0.3	0.4	1.25	0.5	0.3
DL Methionine (feed grade)	0.5	0.5	.	...	.	0.5
	gm.	gm.	gm.	gm.	gm.	gm.
Riboflavin	3	3	3	8	4	3
Niacin	15	15	15	35	.	15
d-alpha-tocopheryl acetate	5	5	5	12	5	. .
Antibiotic†	4-10	4-10	4-10	10-35	6-20	4-10
Arsonic acid‡	45-90	45-90	45-90	110-220	.	45-90
	mg.	mg.	mg.	mg	mg.	mg.
Vitamin B_{12}	3	3	3	8	6	3
Calculated analysis	%	%	%	%	%	%
Min. crude protein	27.1	25.6	20.1	35.3	20.0	19.1
Min. crude fat	2.8	2.9	3.3	3.0	3.5	3.4
Max. crude fiber	5.2	5.7	6.0	7.6	6.6	3.7
Calcium	1.9	1.9	1.6	3.9	2.3	1.5
Total phosphorus	1.0	1.0	0.8	1.5	0.9	0.8
Inorganic phosphorus	0.68	0.67	0.54	1.24	0.66	0.52

* Tallow or grease should not be used unless it has been stabilized with suitable antioxidants and tested for stability.

† The levels suggested for antibiotics are in terms of the salts of the antibiotics. If penicillin is the antibiotic, use the lower level. If aureomycin, terramycin, or bacitracin are used, the higher levels should be employed.

‡ It is recommended that either 3-nitro, 4-hydroxyphenylarsonic acid, at the lower levels shown, or arsanilic acid, at the higher levels, be included.

feeding of turkey broilers up until the time they are changed to this finishing mash. When used for starting turkey broilers it is recommended that the starter mash be used as an all-mash diet right up until the time of changing to the finishing mash and that the change to the finishing mash be made gradually over a period of about 3 days.

Substitutions. Equal parts of wheat shorts and wheat bran may replace ground barley. Dried whey may replace dried buttermilk or dried skimmilk. For every 40 pounds of dried milk replaced with dried whey, increase the amount of soybean oil meal by 30 pounds and reduce the ground wheat by 30 pounds. Steamed bonemeal may be replaced by defluorinated rock phosphate. Other calcium and phosphorus carriers may be used if replacement is made on the basis of calcium and phosphorus content. Vitamin A oil may be replaced by dry vitamin A products on an equal unitage basis. Manganese sulfate may be replaced by other manganese carriers to supply equal levels of manganese. Ground limestone may be replaced by calcium carbonate.

TEXAS. (Agricultural and Mechanical College of Texas, 1954.)

TEXAS TURKEY RATIONS

Ingredients	Turkey Starter All-Mash %	Turkey Grower All-Mash %	Turkey Fattener All-Mash %	Turkey Laying Mash All-Mash %
Ground milo	20	30	35 1/2	40
Ground yellow corn	17 1/2	20 1/2	25	19 1/2
Wheat gray shorts	5	5	5	5
Soybean oil meal (44% protein)	38*	25*	20*	15
Fish meal (60% protein)	6	5	5	6
Dried whey	3	3	3	3
Dehydrated alfalfa leaf meal	5	6	6	6
Steamed bonemeal or equivalent phosphorus supplement	3	3	3	3
Ground limestone or oystershell	2	2	2	2
Salt	1/2	1/2	1/2	1/2
Supplements†				

* Eight per cent of the soybean oil meal may be replaced by 8 per cent of cottonseed meal meeting the following quality specifications: (1) containing no more than 0.1 per cent free gossypol, (2) should have a nitrogen solubility of at least, 70 per cent in 0.02 sodium hydroxide.

† To be added per ton of feed·

1. Manganese sulfate, 1/2 pound
2. Antibiotics· Use either 10 grams of aureomycin, 10 grams of bacitracin, 10 grams of terramycin, or 4 grams of penicillin A combination of two, three, or four of the antibiotics may be used. In making up the combination, use a proportionate part of the above given levels on a per ton basis.
3. Vitamin A: 6,000,000 International units Any source of vitamin A available may be used just so the total number of units added per ton is that given.
4. Vitamin D_3: 2,000,000 International chick units
5. B vitamins:
   - 4 grams riboflavin
   - 10 grams calcium pantothenate (Dextrorotatory)
   - 40 grams niacin
   - 800 grams choline chloride

   It will probably be necessary to obtain choline chloride in the dry form as a 25 per cent supplement
6. Vitamin B_{12}· 6 milligrams
7. Methionine: 1 pound
8. Arsonic acids: Add level according to manufacturer's recommendations (add to starting and growing rations only)

These supplements will be added to the starting, growing, and fattening rations as given. The choline chloride and the methionine may be eliminated from the laying ration.

WASHINGTON. (Washington Poultry Feed Formulas, Poultry Science Department, State College of Washington, Ext. Mimeo. 1186, 1185, and 1184, 1954.)

TURKEY STARTER MASHES

Ingredients	1 %	2 %	3 %	4 %	5 %	6 %
Ground yellow corn or milo*	40.2	37.2	37.2	43.7	40.0	41.5
Soybean oil meal (44% protein)	46.5	46.0	42.0	40.0	39.7	37.2
Fish meal (70% protein)	5.0	5.0	5.0	5.0	5.0	10.0
Meat and bonemeal (50% protein)	...	...	...	5.0	5.0	...
Dehydrated alfalfa or grass (carotene, 12 mg./100 gm.)	2.5	2.5	2.5	2.5	2.5	2.5
Dried brewers' yeast	...	...	4.0	...	...	...
Dried whey	...	4.0	4.0	...	4.0	4.0
Salt (iodized, fine)	0.3	0.3	0.3	0.3	0.3	0.3
Limestone or shell flour	2.0	2.0	2.0	2.0	2.0	2.0
Steamed bonemeal or defluorinated phosphate	3.5	3.0	3.0	1.5	1.5	2.5
Add the following to each ton of feed						
Vitamin A, millions of I.U.	3.5	3.5	3.5	3.5	3.5	3.5
Vitamin D_3, millions of I.C.U.	1.2	1.2	1.2	1.2	1.2	1.2
Riboflavin, gm.	1.6	0.6	...	1.5	0.6	0.5
Calcium pantothenate, gm.	2.6	1.0	...	3.0	1.4	1.5
Choline chloride, lb.	1.0	1.0	1.0	1.0	1.0	1.0
Methionine, lb.	1.0	1.0	1.0	1.0	1.0	1.0
Manganese sulfate lb. (100% pure)	0.4	0.4	0.4	0.4	0.4	0.4
Antibiotic†						

Suggested analysis: protein, 28 per cent; calcium, 2.0 per cent; phosphorus, 1.0 per cent; vitamin A, 4000 International units per pound, vitamin D_3, 600 International chick units per pound, and riboflavin, 2 milligrams per pound.

These mashes may also be used for turkey fryers. The suggested method of feeding follows: During the first 3-4 weeks feed as crushed pellets or crumbled feed. After this feed intermediate size (1/8 inch) pellets. If feather picking develops, mix pellets and mash. After the poults are 6 weeks of age small amounts of cracked or whole grain may be placed with the feed to accustom the turkeys to grain. Feed granite or silica grit of the proper size one day each week.

* Up to 15.0 per cent of ground wheat, ground barley, or finely ground oats may be used to replace an equivalent amount of corn or milo; however, such substitutions will decrease feed efficiency.

† If using diamine or procaine penicillin, use at rate of 3 grams per ton. If using aureomycin, bacitracin or terramycin, use at rate of 10 grams per ton.

TURKEY DEVELOPER MASHES
(8 weeks to maturity)

Ingredients	1 %	2 %	3 %	4 %	5 %
Ground grains*	61.5	49.0	45.0	47.0	55.0
Wheat mixed feed (millrun)*	...	10.0	10.0	10.0	...
Fishmeal (70% protein)	5.0	2.0	...	...	5.0
Meat and bonemeal (50% protein)	...	3.0	...	5.0	...
Soybean oil meal (44% protein)	23.0	20.0	28.0	22.0	14.0
Cottonseed meal (43% protein)	...	...	...	...	10.0
Dehydrated alfalfa or grass (carotene, 12 mg./100 gm.)	5.0	10.0	10.0	10.0	10.0
Limestone or shell flour	2.0	3.0	3.0	4.0	4.0
Steamed bonemeal or defluorinated phosphate	3.5	2.0	3.0	1.0	1.0
Salt (iodized, fine)	1.0	1.0	1.0	1.0	1.0
Add the following to each ton of feed					
Vitamin D_3, millions of I.C.U.	1.2	1.2	1.2	1.2	1.2
Riboflavin (gm.)	1.7	...	...	...	...
Manganese sulfate, lb., (100% pure)	0.4	0.4	0.4	0.4	0.4
Antibiotic†					

Suggested analysis: protein, 20.0 per cent; calcium, 2.0 per cent; phosphorus, 1.0 per cent; vitamin A, 4000 International units per pound; vitamin D_3, 600 International chick units per pound; riboflavin, 2 mg. per pound.

The suggested method of feeding follows: Feed the mash or pellets and whole grain free choice during the entire growing period. Feed granite or silica grit one day each week.

*Ground corn, milo, wheat, barley, or oats may be used singly or in any combination with 0–10 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 35 per cent of the mash.

†If using diamine or procaine penicillin use at rate of 3 grams per ton. If using aureomycin, bacitracin, or terramycin use at rate of 10 grams per ton.

TURKEY BREEDER MASHES AND COMPLETE RATIONS

Ingredients	1 %	2 %	3 %	4 %	5 %
Ground grains*	63.2	53.2	61.2	49.4	29.4
Wheat mixed feed (millrun)*	10.0	15.0	10.0	. . .	15.0
Dehydrated alfalfa or grass (12 mg. carotene/100 gm.)	5.0	10.0	5.0	10.0	20.0
Soybean oil meal (44% protein)	12.0	10.0	9.0	22.0	18.0
Meat and bonemeal (50% protein)	. . .	2.0	. . .	8.0	. . .
Fish meal (70% protein)	4.0	2.0	4.0	. . .	5.0
Dried whey	. . .	2.0	. . .	4.0	4.0
Limestone or shell flour	3.5	3.5	3.5	3.0	3.0
Steamed bonemeal or defluorinated phosphate	2.0	2.0	2.0	3.0	5.0
Salt (iodized)	0.3	0.3	0.3	0.6	0.6
Wheat germ meal	. . .	. . .	5.0	. . .	. . .
Add the following to each ton of feed					
Vitamin A, millions of I.U.	1.0	. . .	1.0	2.0	. . .
Vitamin D_3 millions of I.C.U.	1.0	1.0	1.0	2.0	2.0
Vitamin B_{12}, (mg.)	. . .	3.0	. . .	6.0	. . .
Alpha tocopheryl acetate (gm.)	20.0	10.0	. . .	20.0	. . .
Manganese sulfate, lb. (100% pure)	0.25	0.25	0.25	0.5	0.5
Calcium pantothenate (gm.)	10.0	5.0	10.0	16.0	10.0
Riboflavin (gm.)	2.0	1.5	2.0	3.5	1.0

Suggested analysis: Rations 1 and 2, protein, 16.0 per cent; calcium, 2.0 per cent; phosphorus, 1.0 per cent; vitamin A, 4000 International units per pound; vitamin D_3, 600 International chick units per pound; riboflavin, 2 milligrams per pound. Rations 4 and 5, protein, 20 per cent; calcium, 3.0 per cent; phosphorus 1.5 per cent; vitamin A, 6700 International units per pound; vitamin D_3, 1000 International chick units per pound; riboflavin, 3 milligrams per pound.

Rations 1, 2, and 3 are complete rations and should be fed as mash crumbles or pellets. Rations 4 and 5 are to be fed with grain free choice on the basis of 60 per cent mash and 40 per cent grain.

Limestone grit or shell should be available at all times. Feed granite or silica grit 1 day each week.

*Ground corn, milo, wheat, barley, or oats may be used singly or in combination with 0-15 per cent millrun as long as the combined amounts of barley, oats, and millrun do not exceed 35 per cent of the mash. When the total of millrun, oats, and barley is over 30 per cent, the feed should be pelleted.

WISCONSIN. (University of Wisconsin, 1954.)

WISCONSIN RATIONS FOR TURKEYS

	Starting lb.	Rations lb.	Growing lb.	Rations* lb.	Breeder Rations lb.
Ground yellow corn	210	160	295	295	365
Ground oats	50	50	50	50	100
Wheat bran	50	50	50	50	100
Wheat middlings	50	50	50	50	100
Alfalfa meal	50	50	...	...	100
Meat scrap	100	100	...	50	50
Soybean oil meal	400	400	480	420	150
Fish meal	...	...	...	...	25
Chick size oystershell	20	20	20	20	...
Granite grit	10	10	...	...	...
Special steam bone-meal	20	20	50	40	...
Iodized salt	5	5	5	5	5
Dried whey fortified	...	50	...	...	...
Fish solubles	30	30	...	...	...
300 D feeding oil or powder†	4	4	No	No	5
2000 A feeding oil	2	2	...	...	2
Manganese sulfate (feeding grade)	1/4	1/4	1/4	1/4	1/4
Riboflavin	1 1/2 gm.	...	No	No	1 1/2 gm.
Antibiotic feed supplement‡	Yes	Yes	No	No	...

* With good pasture, free access to grains.
† Based on International chick units.
‡ Use according to manufacturer's directions.

SECTION VI. RATIONS FOR DUCKS

CORNELL. (1954.) The duck starting ration is fed as $^{9}/_{64}$-inch pellets for the first 2 to 3 weeks. The duck growing ration is fed as $^{13}/_{64}$-inch pellets to follow the starting ration. It may be fed until the ducklings are marketed or may be followed by duck fattener for the last 2 weeks before marketing. The duck breeding ration is fed as $^{13}/_{64}$-inch pellets. The mature birds should also be given access to oystershell.

CORNELL DUCK RATIONS

Ingredients	Starter lb.	Grower lb.	Breeder lb.
Corn meal	720	675	580
Wheat standard middlings	300	200	300
Wheat flour middlings	300	300	300
Wheat, ground whole	. . .	200	100
Oats, pulverized	200	200	200
Fish meal (60% protein)	100	50	50
Fish solubles (50% solids)	. . .	. . .	50
Meat scrap (50% protein)	50	100	100
Soybean meal (44% protein)	100	50	50
Alfalfa meal (17% protein)	60	60	100
Yeast, dried brewers'	. . .	. . .	40
Whey, dried	50	50	60
Distillers' solubles, dried	50	50	. . .
Limestone, ground	40	40	60
Dicalcium phosphate	20	15	. . .
Salt, iodized	6	6	6
Vitamin A supplement (4000 A/gm.)	2	2	2
D-activated animal sterol (1500 D/gm.)	1	1	1
Riboflavin supplement (3500-4000 mg/lb.)	0.5	0.5	0.5
Manganese sulfate	0.5	0.5	0.5
Niacin, pure	(30 gm.)	(30 gm.)	(30 gm.)
Vitamin E supplement to supply	. . .	. . .	(5 gm.)
Calculated Analysis:	%	%	%
protein	17.5	16.0	17.5
fat	4.25	4.0	4.0
fiber	4.75	4.5	5.0
calcium	1.65	1.70	2.0
phosphorus	0.95	0.86	0.8

CORNELL RATIONS FOR LAYING DUCKS

(L. M. Hurd and K. F. Hilbert, Duck growing, Cornell Bul. 345, revised, 1948.)

Mashes*

Ingredients	Layer Rations 1 lb.	2 lb.	3 lb.	4 lb.
Yellow corn meal	500	475	475	450
Wheat bran	300	300	300	300
Wheat standard middlings	200	200	200	200
Wheat red dog flour	300	300	300	300
Ground oats, low fiber	200	200	200	200
Soybean meal	150	150	150	150
Meat scrap (55% protein)†	150	100	125	150
Dehydrated alfalfa meal (17% protein)	120	120	120	120
Dried skimmilk	...	50	...	...
Dried buttermilk	...	...	50	...
Dried whey	...	...	...	50
Pulverized limestone	70	70	70	70
Salt	10	10	10	10
Vitamin D from fish oil, feeding oil, or activated animal sterols A.O.A.C. units per pound.‡	650	650	650	650

* To be fed at the rate of 2 parts of mash to 1 part of grain.
† Fish meal may be substituted entirely, or in part, for meat scrap.
‡ Vitamin D may be omitted from the mash when the ducks run outdoors daily.

Grain Mixtures

Ingredients	Modifications 1 lb.	2 lb.	3 lb.	4 lb.	5 lb.
Cracked yellow corn	50	65	40	40	40
Wheat	50	35	40	40	40
Heavy oats	...	...	20	10	10
Barley	..	...	. .	10	...
Buckwheat	...	...	..	..	10

HARPER ADAMS AGRICULTURAL COLLEGE (ENGLAND). Rations for Table Ducklings. (V. K. Tallent, The production of table ducklings, Harper Adams Utility Poultry Jour., 17:357, 1931-1932.)

Ingredients	Starter, First Week, lb.	Grower, 2-7 Weeks, lb.	Fattener for 2 Weeks, lb.
Barley meal	20	40	120 of either
Sussex ground oats	20	40	or a mixture of both
Wheat bran	20	30	...
Wheat middlings	40	60	40
Dried milk	10	...	...
Meat and bonemeal	...	20	30
Cod liver oil	2%	...	...

Developing Rations for Ducks for Eggs. (Duck Notes, Harper Adams Utility Poultry Jour., 13:318 1927-28.)

One to four weeks:	4 or 5 meals daily of a mash made up of 1 part of biscuit meal and equal parts of thirds and Sussex ground oats.
One to two months:	3 meals a day of a mash made up of 1 part of bran and equal parts of Sussex ground oats, maize meal, and thirds, with 1/2 part of fish meal.
Two to four months:	3 meals of a mash made up of 1 part of bran, 3 parts of sharps, 1 part of Sussex ground oats, 1 part of maize meal, and 1/2 part of fish meal.
After 4 months:	Feed 2 meals of the above mash, plus grain, at night. The grain can be made up of wheat and kibbled maize.

Ration for Laying Ducks. (The feeding and management of the laying duck, Harper Adams Utility Poultry Jour., 18:597, 1933.) This ration was fed at the Egg Laying Trials for ducks. The grain feed, of which they get 2 ounces per bird daily, consists in parts by weight of 2 wheat, 1 best clipped white oats, 1 cracked maize, and $\frac{1}{16}$ cracked green peas. The mash ration, in parts dry weight, of which 4 ounces per duck is allowed daily, consists of 3 sharps, 2 Sussex ground oats, 2 maize meal, 1 bran, 1 fish meal, and 1 alfalfa meal.

STATE INSTITUTE OF APPLIED AGRICULTURE, Farmingdale, L. I., New York. (Rations for ducks, Dept. of Poultry, Stencil 1303.)

MASHES FOR MATURE DUCKS

Ingredients	1 lb.	2 lb.
Yellow corn meal	350	300
Wheat bran	200	200
Wheat standard middlings	. . .	100
Second clear flour	125	125
Meat scrap (50% protein)	100	50
Pulverized oats	100	100
Dried skimmilk	50	25
Alfalfa leaf meal	50	50
White fish meal	25	50

DUCK STARTING AND GROWING MASHES
(These mixtures are to be fed from the time the ducklings are a day old until they are marketed)

Ingredients	1 lb.	2 lb.	3 lb.	4 lb.
Yellow corn meal	300	300	375	500
Wheat flour middlings	200	100	. . .	. . .
Red dog flour	. . .	. . .	100	50
Wheat bran	100	150	300	200
Second clear flour	50	150	. . .	. . .
Dried skimmilk	100	. . .	75	50
Pulverized oats	100	100	. . .	50
Meat scrap (50% protein)	50	100	100	100
White fish meal	50	50	. .	. . .
Alfalfa leaf meal	50	50	50	50

Fattening Mash. This mixture is designed for those who want to use a special fattening mash. It may be fed 2 to 3 weeks before the ducklings are marketed. It may follow any of the starting and growing mashes.

	Pounds
Yellow corn meal	500
Wheat bran	150
Second clear flour	125
Pulverized oats	100
Dried skimmilk	50
Meat scrap (50% protein)	50
White fish meal	25

SECTION VII. USING LOCAL GRAIN FOR POULTRY

CORNELL. (New York State College of Agriculture at Cornell University, Department of Poultry Husbandry, Ext. Stencil 194, 1951, and 224, 1953.)

Local grain supplies such as oats, wheat, corn, barley, buckwheat, and rye can be used in poultry feeding in the following ways:

1. Scratch grain mixtures.
2. Combined in ground form with a "mixing mash" or mash concentrate to form a complete poultry mash.
3. Used by the feed manufacturer directly as an ingredient in a formula feed.

Scratch Grain Mixtures. Mash mixtures are usually designed to be fed with grain, by any of a variety of feeding systems, so that about equal amounts of mash and the grain mixture are consumed daily. The simplest way of using home-grown or local grain is to incorporate it in the scratch grain mixture; in fact, unless a farmer has more grain available than is required to meet the need for the scratch grain part of his feeding program, it is usually uneconomical for him to use it in any other way. The feed dealer can also use locally purchased grain to supply a large part of his scratch grain volume. The amounts and proportions of various grains available vary with regions. A single grain mixture will not meet the conditions of all areas, nor will the same mixture always be adaptable to the local supply situation. For this reason, the following table (A) shows suggested maximum usage levels of various grains per ton of mixture, rather than grain mixture formulas as such.

TABLE A. SUGGESTED GRAIN USAGE LEVELS FOR SCRATCH MIXTURES.

Grain	Maximum usage level per ton of scratch mixture lb.
Corn (whole or cracked)	1500
Wheat	1500
Oats, heavy	800
Oats, light	500
Barley	800
Buckwheat	400

Experience has shown it to be more generally satisfactory to use a mixture of grains than a single grain. In order to maintain a high level of available energy and digestibility in the grain mixture, it is suggested that at least half of it should be made up of corn and/or wheat, and not more than half of it from oats, barley, and/or buckwheat. Rye is unpalatable to poultry, and is not readily consumed in grain mixtures.

It has become a common practice to use cracked corn in poultry scratch mixtures. It is, of course, important to use cracked corn in the scratch mixture provided for young growing birds. However, whole corn can be used satisfactorily for growing birds after they are 10 to 12 weeks of age, and for pullets and hens. It is most satisfactory to begin feeding whole corn during the growing period so that the birds are accustomed to eating whole corn before they enter the laying houses. If the birds have been accustomed only to cracked corn during the growing period and it is desired to shift them to whole corn after they have entered egg production, it is best to shift gradually in order to avoid a sudden decrease in feed consumption.

In some areas facilities for shelling corn may not be readily available, and it would be desirable to feed corn on the cob. This can be done easily by giving cob corn in the morning in the litter and at night feeding a scratch mixture that has a low proportion or no corn in it. It would be best to weigh the cob corn as fed in order to follow the amount eaten and be able to control grain consumption. The cob will constitute about 1/5 the weight of cob corn. Normally about half of the total feed intake of mature birds will be scratch grain, amounting to about 12 to 15 pounds per 100 birds per day; feeding 7½ pounds of cob corn per day will supply 6 pounds of shell corn, which would be about half of the scratch feed requirement of the birds. This can be adjusted according to season, egg production, and the proportion of corn desired in the scratch portion of the diet.

Formulation of Mixing Mashes. The utilization of local grains in the mash part of the ration is simplified by the use of a so-called "mixing mash." Such mixtures are essentially the nongrain part of a complete poultry ration, designed to be combined in a definite proportion with ground grains.

Tables I and II show the recommended formula patterns and required nutrient content of mixing mashes Tables III to VII show examples of mixing mash formulas compounded according to the recommended patterns to meet the nutrient requirements.

General considerations covering the choice of ingredients within the ingredient classes are discussed below. (The tables appear at the end of the Appendix.)

Vegetable Proteins. Soybean meal and other vegetable protein supplements are the most plentiful protein sources available for poultry feeding. They can be used to supply most of the supplementary protein needed in poultry mashes. Soybean meal, the ingredient of this class available in greatest supply, can be used alone or in combination with corn gluten meal or peanut meal. Corn gluten and peanut meal should not make up more than 1/4 the total of this class of ingredients used in a mash. Cottonseed meal can be used similarly in combination with soybean meal in mashes for growing birds but should be avoided in rations for hens. Linseed meal cannot be recommended for use in any poultry ration because of its growth-retarding effect.

Animal Proteins. These products serve as sources of protein, minerals, vitamin B_{12}, and at least one other still unidentified nutrient. The minimum levels recommended for starter, confinement grower, and breeder mashes are the amounts needed to aid in supplying the unknown nutrient(s). The lower recommended figure refers to the minimum level of fish products when used alone; the higher figure indicates the approximate level of meat scrap when used alone. A combination of products appears to be preferable. Depending upon cost and availability, levels higher than the indicated minimum amounts can be used in all poultry mashes; the amounts of protein, calcium, phosphorus, and vitamin B_{12}, contributed by the animal products, will accordingly determine the amounts of these nutrients needed from other sources.

The recommended levels of vitamin B_{12}, indicated in the table showing required composition of poultry mashes, refer to the amounts supplied by fish products, meat scrap, and vitamin B_{12} supplements. It is desirable to know the B_{12} content of the particular fish and meat products used, and this may be determined by microbiological assay. When such analytical values are not available, an approximation of the B_{12} content of the mash may be calculated by assigning values of 40 micrograms of vitamin B_{12} per pound of fish meal, 70 micrograms per pound of fish solubles, and 15 micrograms per pound of meat scrap.

Other B-Vitamin Carriers. Included in this class of feedstuffs are dried milk products, dried yeast, dried distillers' solubles, and fermentation solubles. These ingredients are valuable sources of many of the known B-complex vitamins.

The levels recommended are intended to aid in supplying the unknown nutrient(s) referred to above. Because it appears likely that more than one unidentified nutrient may be required in the ration, it is considered wise to use these carriers in combination with animal proteins.

Dehydrated Alfalfa Meal. This product is an important source of vitamin A activity and contributes materially to the protein and riboflavin content of a mash, but it is desirable to limit its use because of its low available energy value. It is, therefore, necessary to use a high-quality meal in order to supply sufficient vitamin A activity at the low-usage levels recommended. As shown in the formula examples, using alfalfa meal containing 100,000 units of vitamin A activity per pound at a level of 250 pounds per ton will meet the requirement for vitamin A in laying and breeding rations if yellow corn makes up approximately half of the grain used in the mash and in the scratch grain mixture. If the alfalfa meal available does not contain sufficient vitamin A activity to meet the requirement at the feeding levels recommended, additional vitamin A should be supplied in another form, such as a vitamin feeding oil, rather than by exceeding the recommended alfalfa meal levels.

Calcium and Phosphorus Supplements. The phosphorus re-requirements are shown both as total phosphorus and "available phosphorus." The available phosphorus content of a mash is the amount supplied by the animal products and the inorganic supplements (bonemeal, defluorinated phosphate, etc.) plus 30 per cent of the rest of the phosphorus of the mash. Calculating available phosphorus gives a more accurate appraisal of the phosphorus value of a mash than does the total phosphorus content.

The phosphorus sources listed in the pattern table are essentially equivalent in the availability of their phosphorus. In choosing a phosphorus supplement, care should be taken to insure that the product is intended for poultry feeding and has a sufficiently low content of fluorine.

The calcium levels recommended for layer and breeder mashes, shown in the table on required nutrient composition, do not meet the total requirement of hens for egg production. Experimental studies have shown that it is undesirable to use a calcium level in the mash sufficiently high to meet this requirement. These rations, therefore, should be supplemented by giving the hens free access to oystershell or some other cal-

cium supplement. It is also advisable to feed such calcium supplements free choice in addition to growing mash.

Vitamin D. The recommended vitamin D levels are shown in International chick units, based on the new vitamin D_3 standard now in official use. Feeding oils and D-activated animal sterols are equally effective sources of vitamin D, unit for unit.

Other Riboflavin and B_{12} Sources. Riboflavin supplements and vitamin B_{12} supplements of guaranteed vitamin content are generally available and can be highly useful in meeting the requirements for these vitamins. The levels of other vitamin-rich feedstuffs in the formula, particularly when amounts greater than the minimum levels are supplied, will determine whether and in what amounts special vitamin supplements should be used.

Use of Mixing Mashes. The mixing mashes allow a wide degree of flexibility in the choice and proportion of grains that can be combined with them. The main considerations involved in choosing the grains are to maintain a sufficiently high level of productive energy (Table VIII) and over-all digestibility together with suitable texture and palatability.

Table B presents suggested maximum usage levels of the common grains per ton of finished mash mixture. Here again it is generally preferable to employ two or more grains rather than a single grain. Because of their high-energy value, corn and/or wheat should constitute at least half of the grain used; conversely, the lower-energy grains should not comprise a total of more than half the grain used.

To make an adequate mash for a particular purpose, the proper mixing mash must be used. In other words, a layer

TABLE B. SUGGESTED GRAIN USAGE LEVELS FOR MASH MIXING

Ground grain	Maximum level per ton lb.	Suggested combinations for use with mixing mashes. (1200 lb. ground grain to be mixed with 800 lb. mixing mash)					
Corn meal	1000	800	...	600	800	800	600
Corn and cob meal	800	...	800	...	...	...	...
Wheat (coarse, ground, or crushed)	1000	200	400	...	...	...	200
Oats, heavy	600	200	...	600	...	...	200
Oats, light	400	...	...	...	400	...	...
Barley	600	...	...	...	...	200	...
Buckwheat	400	...	...	...	...	...	200
Rye (finely ground)	400	...	...	...	...	200	...

mash cannot be made by combining grain with a mixing mash designed to make a starter. Nor is there any simple way that one type of ration can always be converted to another.

The starter mash is intended to be used as an all-mash ration. To use this formula for broilers, it will be advisable to use corn gluten meal to obtain the pigmentation desirable in meat birds; a level of 125 pounds per ton of mixing mash will result in 50 pounds per ton of broiler mash.

The grower, layer, and breeder mashes produced by the respective mixing mashes are 20 per cent protein mashes intended to be fed with approximately equal grain intake according to the usual feeding systems.

Grain-Based Mash Formulas. Use of a large proportion of local grain as ingredients in a mash formula, either in branded feeds or through custom mixing, is a third alternative. Such a procedure requires the development of balanced formulas such as those presented in the circular on poultry rations.

The suggested usage levels of ground grain summarized in Table B for mixing mashes apply directly to this method of mixing as well. Examples of grain-based layer mashes are shown in Table IX to illustrate the wide range of grain proportions that can be used. Other types of rations similarly based on various proportions of local grains can be formulated to meet the specific requirements of growing or breeding chickens by following the recommendations summarized in the circular on poultry rations.

TABLE II. REQUIRED NUTRIENT CONTENT OF MIXING MASHES

Nutrient	Starter or Broiler (All-Mash)	Growers (with grain) Confinement	Growers (with grain) Pasture	Layer (With grain)	Breeder (With grain)
Protein, %	32	32	32	32	32
Calcium, %	2.5-3.5	4-5	4-5	5-6	5-6
Phosphorus					
Total, %	1.1	1.8	1.8	2.5	2.5
Available, %	0.9	1.6	1.6	1.8	1.8
Riboflavin, mg./lb	3.3	2.5	...	2.5	4.5
Vitamin B_{12}, μg/lb.	4	4	...	...	8
Vitamin D, I.C.U /lb.	340	675	...	1,700	1,700
Vitamin A, I.U./lb.					
If no corn used	5,000	10,000	...	16,500	16,500
If 50% of grain in mash and scratch is corn	3,500	6,000	...	12,500	12,500

TABLE III. EXAMPLES OF MIXING MASHES, STARTER OR BROILER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Wheat flour (or standard) middlings	350	360	225	210
Soybean meal	900	900	750	800
Corn gluten meal	. . .	. . .	250	. . .
Peanut meal	. . .	. . .	. . .	250
Fish meal	125	250	. . .	. . .
Fish solubles	. . .	. . .	125	. . .
Meat scrap	125	. . .	125	250
Corn dried distillers' solubles	125	. . .	250	. . .
Dried whey	125	125	. . .	250
Dried brewers' yeast	. . .	125	. . .	. . .
Dehydrated alfalfa meal	125	125	125	125
Riboflavin supplement to supply (mg. riboflavin)	1250 mg.	. . .	1400 mg.	. . .
Vitamin B_{12} supplement to supply (mg. B_{12})	3 mg.	. . .	. . .	5 mg.
D-activated animal sterols (1500 I.C.U./gm.)	2	2	2	2
or				
Vitamin feeding oil (300 D, 1500 A)	10	10	10	10
Steamed bonemeal	35	35	60	25
Limestone	70	70	75	75
Salt (iodized)	15	15	15	15
Manganese sulfate (65% feeding grade)	1	1	1	1
Protein, %	34	36	34	34
Calcium, %	3	2.8	3.1	3.3
Phosphorus: total %	1.3	1.3	1.3	1.3
available %	0.9	0.9	0.9	0.9
Vitamin A,* I.U./lb.	6250	6250	6250	6250
Vitamin D, I.C.U./lb.	680	680	680	680
Riboflavin, mg./lb.	3.3	3.3	3.3	3.3
Vitamin B_{12},† μg/lb.	5	5	5	4

* Assuming use of alfalfa meal containing 100,000 International units vitamin A activity and no vitamin feeding oil.

† From animal proteins and vitamin B_{12} supplement.

TABLE IV. EXAMPLES OF MIXING MASHES, CONFINEMENT GROWER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Wheat flour (or standard) middlings	120	225	. . .	. . .
Soybean meal	900	775	750	785
Corn gluten meal	. . .	. . .	250	. . .
Peanut meal	. . .	. . .	. . .	250
Fish meal	125	250	. . .	. . .
Fish solubles	. . .	. . .	125	. . .
Meat scrap	125	. . .	125	250
Corn dried distillers' solubles	250	. . .	125	. . .
Dried whey	. . .	125	125	250
Dried brewers' yeast	. . .	125	. . .	. . .
Dehydrated alfalfa meal	250	250	250	250
Vitamin B_{12} supplement to supply (mg. B_{12})	3 mg.	. . .	. . .	6 mg.
D-activated animal sterols (1500 I.C.U./gm)	2	2	2	2
or				
Vitamin feeding oil (300 D, 1500 A)	10	10	10	10
Steamed bonemeal	150	150	175	140
Limestone	50	75	50	50
Salt (iodized)	25	25	25	25
Manganese sulfate (65% feeding grade)	1.2	1.2	1.2	1.2
Protein, %	34	34	33	34
Calcium, %	4.3	4.5	4.4	4.5
Phosphorus: total, %	2.0	1.9	1.9	1.9
available, %	1.6	1.6	1.6	1.6
Vitamin A,* I.U./lb.	12,500	12,500	12,500	12,500
Vitamin D, I.C.U./lb.	680	680	680	680
Riboflavin, mg./lb.	2.5	3.6	3.4	3.7
Vitamin B_{12},† μg./lb.	5	5	5	5

* Assuming use of alfalfa meal containing 100,000 International units vitamin A activity and no vitamin feeding oil

† From animal proteins and vitamin B_{12} supplement

TABLE V. EXAMPLES OF MIXING MASHES, PASTURE GROWER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Wheat flour (or standard) middlings	300	225	225	450
Soybean meal	1350	1050	1050	1000
Corn gluten meal	...	250	...	...
Peanut meal	...	...	250	...
Fish meal	...	...	...	125
Meat scrap	...	...	...	125
Corn dried distillers' solubles	...	125	...	...
Dried whey	...	...	125	...
Steamed bonemeal	225	225	225	150
Limestone	75	75	75	100
Salt (iodized)	50	50	50	50
Manganese sulfate (65% feeding grade)	1.2	1.2	1.2	1.2
Protein, %	33	34	33	35
Calcium, %	4.7	4.7	4.8	5.0
Phosphorus: total, %	2.0	2.0	2.0	1.9
available, %	1.6	1.6	1.6	1.6

TABLE VI. EXAMPLES OF MIXING MASHES, LAYER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Wheat flour (or standard) middlings	500	100	125	30
Soybean meal	1,100	1,030	950	1,000
Corn gluten meal	...	...	...	125
Peanut meal	...	250	...	...
Fish meal	...	...	125	125
Meat scrap	250	...	125	...
Corn distillers' dried solubles	...	...	125	...
Dried whey	...	...	...	125
Dehydrated alfalfa meal	250	250	250	250
Riboflavin supplement to supply (mg. riboflavin)	1,000 mg.	1,000 mg.	500 mg.	...
D-activated animal sterols (1500 I.C.U./gm.)	5	5	5	5
or				
Vitamin feeding oil (300 D, 1500 A)	25	25	25	25
Steamed bonemeal	225	250	200	225
Limestone	50	70	50	70
Salt (iodized)	50	50	50	50
Manganese sulfate (65% feeding grade)	1.2	1.2	1.2	1.2
Protein, %	34	34	35	34
Calcium, %	5.6	5.2	5.5	5.2
Phosphorus; total, %	2.4	2.1	2.2	2.1
available, %	2.0	1.8	1.9	1.8
Vitamin A,* I.U./lb.	12,500	12,500	12,500	12,500
Vitamin D, I.C.U./lb.	1,700	1,700	1,700	1,700
Riboflavin, mg./lg.	2.5	2.5	2.5	2.7

* Assuming use of alfalfa meal containing 100,000 International units vitamin A activity and no vitamin feeding oil.

TABLE VII. EXAMPLES OF MIXING MASHES, BREEDER MASHES

	lb./ton	lb./ton	lb./ton	lb./ton
Soybean meal	820	700	700	635
Corn gluten meal	...	125	...	...
Peanut meal	...	...	...	125
Fish meal	200	250	...	...
Fish solubles	...	...	200	...
Meat scrap	200	...	200	350
Corn distillers' dried solubles	125	...	250	200
Dried whey	125	225	100	200
Dried brewers' yeast	...	125	...	...
Dehydrated alfalfa meal	250	250	250	250
Riboflavin supplement to supply (mg. riboflavin)	3,000 mg.	700 mg.	1,000 mg.	1,600 mg.
Vitamin B_{12} supplement to supply (mg. B_{12})	7 mg.	8 mg.	...	12 mg.
D-activated animal sterols (1500 I.C.U./gm.)	5	5	5	5
or				
Vitamin feeding oil (300 D, 1500 A)	25	25	25	25
Steamed bonemeal	150	180	175	140
Limestone	75	50	75	50
Salt (iodized)	50	50	50	50
Manganese sulfate (65% feeding grade)	1.2	1.2	1.2	1.2
Protein, %	34	34	32	33
Calcium, %	5.4	4.7	5.2	5.5
Phosphorus, total, %	2.2	2.1	2.1	2.1
available, %	1.9	1.8	1.8	1.8
Vitamin A,* I.U./lb.	12,500	12,500	12,500	12,500
Vitamin D, I.C.U./lb.	1,700	1,700	1,700	1,700
Riboflavin, mg./lb.	4.5	4.5	4.5	4.5
Vitamin B_{12},† μg./lb.	9	8	8	8

* Assuming use of alfalfa meal containing 100,000 International units vitamin A activity and no vitamin feeding oil.

† From animal proteins and vitamin B_{12} supplement.

TABLE VIII. RELATIVE PRODUCTIVE ENERGY CONTENT OF SOME COMMON GRAINS AND GRAIN PRODUCTS.

	Productive energy* Calories per pound
High energy feedstuffs	
Corn	1145
Milo	1144
Kaffir grain	1076
Wheat	1024
Wheat red dog flour	1020
Medium energy feedstuffs	
Corn and cob meal	920
Heavy oats	817
Barley	811
Rye	810
Wheat flour middlings	720
Low energy feedstuffs	
Buckwheat	700
Light oats	642
Wheat standard middlings	581
Wheat bran	478

* From Texas Agr. Expt. Sta. Bull. 678 (1946) by G. S. Fraps.

TABLE IX. EXAMPLES OF GRAIN-BASED LAYER MASHES (TO BE FED WITH EQUAL GRAIN INTAKE)

	lb./ton	lb./ton	lb./ton	lb./ton	lb./ton
Corn meal	1000	900	800	300	600
Wheat (coarse, ground, or crushed)	200	. . .	. . .	600	. . .
Ground oats	. . .	300	200	300	600
Ground barley	. . .	.	200	. . .	. . .
Soybean meal	500	500	470	450	450
Meat scraps	100	100	100	100	100
Alfalfa meal	100	100	100	100	100
Steamed bonemeal	90	90	90	100	100
Limestone	20	20	20	20	20
Salt	20	20	20	20	20
Manganese sulfate	0.5	0.5	0.5	0.5	0.5
D-activated animal sterol	2	2	2	2	2
or					
Vitamin feeding oil (300 D, 1500 A)	10	10	10	10	10
Riboflavin supplement to supply (mg. riboflavin)	300 mg.	300 mg	300 mg	300 mg	300 mg.

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